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FARM-LEVEL ANALYSIS OF IRRIGATED CROP PRODUCTION IN AREAS WITH SALINITY AND DRAINAGE PROBLEMS

March 1988

This report presents the results of a study conducted for the Federal-State Interagency San Joaquin Valley Drainage Program. The purpose of the report is to provide the Drainage Program agencies with information for consideration in developing alternatives for agricultural drainage water management. Publication of any findings or recommendations in this report should not be construed as representing the concurrence of the Program agencies. Also, mention of trade names or commercial products does not constitute agency endorsement or recommendation.

The San Joaquin Valley Drainage Program was established in mid-1984 as a cooperative effort of the U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, U.S. Geological Survey, California Department of Fish and Game, and California Department of Water Resources. The purposes of the Program are to investigate the problems associated with the drainage of irrigated agricultural lands in the San Joaquin Valley and to formulate, evaluate, and recommend alternatives for the immediate and long-term management of those problems. Consistent with these purposes, Program objectives address the following key areas: (1) Public health, (2) surface- and groundwater resources, (3) agricultural productivity, and (4) fish and wildlife resources.

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Under

U.S. Bureau of Reclamation
Cooperative Agreement No. 7-FC-20-04990

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January 1988

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Farm-level Analysis of Irrigated Crop Production In Areas with Salinity and Drainage Problems

Farmers affected by soil salinity and high water tables can alter cropping patterns and water use to maintain productivity in the short term. Leaching water will remove salts from the root zone and subsurface drainage systems can be installed to manage the soil water level, in fields with perched water tables. These practices are effective when the salt content of irrigation water is not excessive and when adequate drainage and disposal facilities exist. In recent years, the environmental and technical costs of developing drainage outlets and/or treatment facilities have received increased attention. Some of these costs have resulted in restrictions on drainage outflows in some locations.

The purpose of this research is to examine farm-level responses to worsening salinity and drainage conditions and to provide information on the likely responsiveness of growers to policy alternatives which may be proposed in order to manage the quantity and quality of drainage water generated on a local or regional basis. Results will be useful in formulating recommendations for growers faced with changes in drainage outflow constraints and in evaluating regional models of agricultural production and hydrologic balances.

This report describes progress made to date in four areas of research which will contribute to the above objectives:

1. Examination of farm-level economic impacts of salinity and high water tables.
2. Estimation of crop-specific production functions for crops typically grown in drainage problem areas of the San Joaquin Valley.

3. Interviews with growers who have produced crops in areas with and without salinity and drainage problems.

4. Collection and analysis of soil and water quality data in a drainage problem area.

A fifth section of the report describes how the current efforts and results will be useful in future work to complete the goals of the project.

1. Farm-level Economic Impacts of Salinity

Yields of salt-sensitive crops will decline if soil and water salinity cannot be managed effectively. Farmers will shift to growing salt tolerant crops when it is no longer profitable to produce the sensitive ones. The ultimate economic effects of salinity can therefore be described by examining changes in yields and cropping patterns, over time. Observed changes in these, however, may also be caused by market factors such as changes in relative prices. Salinity effects need to be separated from market effects.

Some of the costs associated with crop yield losses due to salinity and high water tables are examined in this study. Farm-level, time-series data on yields and cropping patterns in an irrigation district on the west side of California's San Joaquin Valley are analyzed. The district is in an area known for its problems with salinity and high water tables. Changes in crop yields and the average value of land productivity, over time, are compared with trends throughout a larger production area. The purpose is to identify yield effects that may be due to salts and high water tables in the smaller district.

Background

The 10,000-acre Broadview Water District is located in the northwest corner of Fresno County. Surface water is the major source for

irrigation in Broadview and has generally been available in adequate amounts since 1957. In contrast, a drainage outlet has not always been available and the district had to recycle all of its mingled surface (tailwater) and subsurface drainage water through 1982. This resulted in the application of high-salt irrigation water and the accumulation of salts in district soils.

Broadview's fresh water supply is delivered from the Sacramento River Delta, via the federal Delta-Mendota Canal. The average salinity level of the fresh water supply ranges from 200 to 400 parts per million of total dissolved solids. These values are typical of good quality canal water in the San Joaquin Valley.

Water delivered to Broadview growers is a combination of fresh water and mingled surface and subsurface drainage waters collected in the main district drain. The district had to recycle all of its high-salt drain water for many years, since a disposal outlet was not available until 1983. The ratio of drain water to fresh water in quantities actually delivered to growers increased, over time, from near zero in the early 1960's to about 50% in the early 1980's.

District personnel began collecting soil and water salinity information in 1980. The average level of salinity in the Broadview drain ranged from 2,700 to 2,960 parts per million, total dissolved solids, from 1980 through 1982. Several readings indicate salinity levels greater than 5,000 parts per million. Fresh canal water salinity averaged from between 300 to 350 parts per million, during this period. The blended drainage and fresh water delivered to growers occasionally exceeded 5,000 ppm, but averaged from between 1,800 to 2,150 parts per million. These measurements imply that salts had

accumulated in district soils and contributed to significant increases in the salinity level of water applied to crops.

Yield and Acreage Data

Farm-level data on crop acreages and yields in Broadview were collected from annual reports submitted to the district. Throughout the data collection process, district growers suggested that cropping patterns had shifted significantly during the 1970's. The consensus was that high-value crops such as tomatoes, melons, and alfalfa seed had been replaced with lower value, salt-tolerant cotton and sugarbeets as soil salinity problems increased.

Annual crop production and yield data for Fresno County were obtained from the agricultural commissioner's reports. These data provide information on the total acreage and average yields of crops grown in the county. Unlike Broadview, most other areas of the county are not adversely affected by salinity or high water tables. Since growers throughout the county face similar technological and market conditions, significant differences between the county and the district in yields and cropping patterns may be attributable to deteriorating soil and water conditions in Broadview.

Cotton acreage increased over time in both Broadview and Fresno County as whole. Differing trends are apparent for tomatoes and alfalfa seed (Figure 1). Acreages of these crops countywide either remained constant (tomatoes) or increased (alfalfa seed) after the early 1970's, but they declined in Broadview. Tomato acreage in Broadview was greatest in 1973, declining to zero in 1982. Alfalfa seed acreage fell from nearly 4,000 in 1970 to 560 in 1982. Acres in sugarbeets have remained constant in Fresno County but have increased in the water district.

These differing trends for tomatoes and alfalfa seed motivate examination of crop yields in the two areas to determine if these were also deverging, over time. Cotton yields per acre have generally been higher in Broadview than in Fresno County. Yields of tomatoes in Broadview were consistently higher than the county average through 1973. District tomato yields were highest in the middle to late 1960's and declined in the 1970's. County yields were at or above the Broadview level from 1974 through 1982.

Yields of alfalfa seed increased in the early 1960's in Broadview, before falling at the end of the decade. Despite this decline, yields were at or above those in Fresno County for the 11 years including 1971 through 1981.

One important reason for the reduced alfalfa seed yields and acreage in Broadview in 1969 and the early 1970's was the decline of alkali bee populations. Broadview growers report that these bees are much preferred to normal honey bees for pollination, because (1) alkali bees are less distracted by blossoms of other crops in neighboring fields, and (2) they are better adapted to and more persistent in the difficult task of distributing alfalfa seed pollen. According to growers, bees are a key input in growing alalfa seed, and difficulties in obtaining good pollination can significantly affect crop yields.

Barley and wheat yields have generally been higher in Broadview than in Fresno County, with exceptions in some years. Sugarbeet yields were higher in Broadview through 1974, while county averages were greater in 1976, 1979, and 1980.

Examination of crop yields from a time-trend perspective suggests important differences that evolved between 1962 and 1982. Cotton and

barley yields remained relatively constant in both locations throughout these years. Tomato yields increased in Fresno County while declining in Broadview. Alfalfa seed yields remained constant in the county while declining in the water district. Wheat yields display a positive time trend in each region. Sugarbeet yields are described by a positive trend in Fresno County, while a flat time line is suggested for sugarbeets in Broadview.

Yields and Revenues, By Period

Acreage and yield trends in Broadview and Fresno County suggest important differences for some crops. The crops examined here represent varying degrees of salt sensitivity. Barley, wheat, cotton, and sugarbeets are generally regarded as salt tolerant crops, while tomatoes and alfalfa seed are relatively sensitive (Maas and Hoffman). Site-specific soil and water table conditions, irrigation water quality, and management practices can influence the impact which salts have on yields and the longevity of crop production.

Broadview cropping patterns indicate increasing acreages of cotton over time as the importance of other crops has diminished. These changes may be caused by both technological and market factors, in addition to the effects of salinity and high water tables. A closer review of acreages and yields, by time period, suggests which crops may be responding to soil salinity and high water tables.

Information on the history of Broadview's re-circulating program motivates examination of crop yields in four separate time periods. These are chosen to correlate with distinct changes in cropping patterns, subsurface drainage installations, and drainage outlet availability in the Broadview Water District. The periods are 1962

through 1970, 1971 through 1976, 1977 through 1982, and 1983 through 1986.

The first period includes the years prior to installation of subsurface drains in the district. Barley, cotton, and melons were the major crops grown initially. Alfalfa seed acreage increased during this period, while melons and barley gradually declined. Tomatoes were introduced in the late 1960's, but acreage of this crop declined briefly, prior to the installation of subsurface drains.

The second period is one in which leaching fractions (the portion of water applied in excess of plant requirements) increased, as subsurface drains were installed and the flushing of salts became feasible. Tomato acreage reached a peak in 1973 and remained high through 1975. Alfalfa seed acreage declined throughout the period, while cotton plantings increased moderately. The third period, 1977 through 1982, was dominated by cotton production, as tomato and alfalfa seed acreage declined to near-zero levels.

Broadview's drainage outlet was constructed in 1982 and the first drain water releases occurred in January of 1983. The fourth time period includes the first four years of crop production following installation of a drainage outlet. During this period, the quality of irrigation water delivered to growers improved markedly, as smaller amounts of drain water were blended into the delivery canal. The average salinity of delivered water fell from 1,809 parts per million, total dissolved solids, in 1982 to 592 parts per million in 1983 and remained in the 400 part per million range for the next three years. This occurred as the portion of mingled drainage water in total deliveries declined from 41 percent in 1982 to 18 percent in 1983.

The average salinity of mingled tailwater and subsurface drain water fell from 2,713 parts per million in 1982 to 2,284 ppm in 1983. The average rose again in 1984, but declined in both 1985 and 1986. This downward trend in drain water salinity may indicate that soil salt concentrations were declining, as accumulated salts were finally being removed from district soils.

Broadview tomato acreage increased from zero in 1982 to 750 acres in both 1985 and 1986. Melon plantings increased from 455 acres in 1982 to 790 acres in 1985 and 670 acres in 1986. Acreage in alfalfa seed grew from 560 in 1982 to 630 acres in 1985 and 705 acres in 1986.

Average Broadview yields of selected crops during the four time periods are compared with those for Fresno County in Table 1. Cotton, alfalfa seed, barley, and wheat yields follow similar time trends in each area, with the Broadview average yields being higher than those in the county. Average yields of tomatoes and sugarbeets follow different trends. The average tomato yield in Broadview declined in both the second and third periods, while these averages increased in Fresno County. The average sugarbeet yield declined in the third period in Broadview, while rising in the remainder of the county. Average yields of all crops increased between the third and fourth periods in both locations.

Observed changes in average crop yields represent one of the factors which determine the relative profitability of crop alternatives. Other factors include changes in relative prices. Prices reported for crops in Fresno County, over time, are generally similar to those received by Broadview growers.

Average per-acre revenues for the selected crops are calculated by multiplying average yields by the average prices received (Table 2). Cotton and wheat revenues are consistently higher in the district than in Fresno County. Broadview nominal returns from alfalfa seed production are at or above the county average in all periods. Tomato, barley, and sugarbeet returns fall below the county average in the third period. Revenues for all crops are greater in Broadview than in Fresno County, following improvements in the drainage situation.

The average per-acre cotton revenue increased by 57 percent in Broadview between the second and third periods, while tomato returns declined by 8 percent. These trends may indicate a change in the relative profitability of growing tomatoes and cotton in Broadview during these periods. Alfalfa seed and sugarbeet revenues were also rising at a slower rate than cotton returns between periods two and three.

One estimate of the economic value of a drainage outlet in Broadview is obtained by examining the yield improvements between the third and fourth periods. These increases are adjusted downward to reflect percentage improvements in county average yields that also occurred during those years. This is done to allow for improvements in technology, prevailing weather conditions, and/or reductions in pest problems. The net yield increase in Broadview is then attributed to improved soil and water conditions.

Percentage yield increases are greater in Broadview than in Fresno County for all crops except cotton (Table 3). In Broadview, the net yield increase, or portion of the 15.5-ton increase in tomato yields attributed to drainage improvements, is 13.5 tons (Table 4). The value

of this increase, at the average nominal price received during 1983 through 1986, is $698 per acre. Similar values range from $37 per acre for wheat to $109 for alfalfa seed.

Summary

Compelling evidence of crop responsiveness to improvements in drainage conditions is provided by increases in average crop yields for the four-year period following installation of a drainage outlet in the Broadview Water District. Average yields of the six crops examined here exceeded county averages during these years. Yields of salt-sensitive tomatoes and alfalfa seed responded by 80 percent and 56 percent, respectively. Average yields of salt-tolerant barley, wheat, and sugarbeets have also improved in Broadview, at a rate exceeding Fresno County yield increases, during the most recent period. This suggests that even crops which are considered to be tolerant of soil salinity may be adversely affected by continuous recycling of all drain water, over a prolonged period of time. Yields of these crops have responded positively to improvements in the quality of irrigation water and reductions in soil salinity, made possible by improving the drainage situation in Broadview.

The value of obtaining the drainage outlet and improving soil and water conditions is estimated for selected crops. These data, while pertaining specifically to salinity conditions and yield improvements in the Broadview Water District, provide an indication of the costs associated with yield reductions due to salinity and high water tables. An additional indication is that the effectiveness of leaching programs may be limited in an area which does not have a drainage outlet. Cotton and wheat yields remained constant or increased after subsurface drains

were installed in Broadview, but yields of tomatoes, alfalfa seed, and sugarbeets declined prior to installation of the drainage outlet.

Detailed analysis of the production relationships underlying the observed changes in Broadview crop yields, over time, is described in the following section of the report.

2. Crop-specific Production Functions

Farm-level crop production functions describe the responsiveness of crop yields to changes in the level of inputs and other factors. These are often estimated using farm-level data on yields, input use, and soil and water quality factors, when these data are available. Crop-specific production functions describing yields as a function of the quantity and quality of applied water and soil quality are useful in predicting crop responsiveness to changes in drainage situations. Production functions are also an integral part of any behavioral model of grower response to salinity and drainage policy alternatives.

The relationship between inputs applied in production of crops and the yields produced may change, over time, in response to deteriorating soil and water conditions. Estimation of this relationship in a way that includes the effects of soil and water quality is desirable.

In the absence of detailed data on soil and water quality, adjustments must be made in the estimation procedure to account for the effects of these variables. One useful approach is to gather information from growers which describes the effect of changing soil and water quality on crop production practices and yields. Another approach is to examine historical data to determine when significant changes in quality variables may have occurred. Shift variables pertaining to identified time periods can then be included in an estimation procedure.

Distinct changes in salinity and drainage conditions in the Broadview Water District, during four time periods, are described in the first section of this report. Crop-specific production functions are estimated for these time periods, allowing shifts in the relationships to correspond to changes in soil and water conditions. Estimated shifts

in the production functions are used to describe the empirical effects of salinity and high water tables on crop yields. A multicrop production framework which is appropriate for use with the data available from Broadview is used for this analysis.

A Multicrop Production Model

The data collected from Broadview Water District include crop acreages, yields, revenues, and the total amount of water applied by each grower. Crop-specific water application rates were not recorded until 1985. Hence, an empirical framework allowing limited observations on variable input use is required. The multicrop production model presented by Just, Zilberman, and Hochman is appropriate for this empirical situation, since certain variable input use rates are not observed. This framework is used here to estimate production function parameters and the unobserved crop-specific irrigation rates.

Farmers are assumed to be maximizing expected net revenues, subject to production constraints:

$$(1) \qquad \max_{y,\, X,\, x_2} E(\pi) = E(p^T y - w_2 x_2)$$

$$\text{subject to:} \quad y = f(X)$$

$$X\iota = x$$

where: $y = (y_1, \ldots, y_K)^T$, a vector of farm outputs;

$x = (x_1, x_2)^T$, a vector of land and water inputs;

$X = [x_{jk}]$, a (2 by K) matrix of input allocations;

$\iota = (1, 1, \ldots, 1)^T$;

w_2 = price of irrigation water;

π = net revenue;

Cobb-Douglas production functions for the case of two inputs, land and water, are specified as:

$$(2) \qquad y_{ik} = x_{i1k}^{\alpha_{1k}} \, x_{i2k}^{\alpha_{2k}} \, e^{\epsilon_{ik}^{y}}$$

where: y_{ik} = output of the kth crop for farmer i;

x_{i1k} = acreage planted to the kth crop;

x_{i2k} = irrigation water applied to the crop;

α_{jk} = production elasticity, j = 1, 2;

ϵ_{ik}^{y} = a random error term for the kth production function, $N(0, v_k)$;

e = the natural exponent.

Output price is a random variable and is treated as in Just, Zilberman, and Hochman. Marginal value product relationships are substituted for the unobserved irrigation water applications, according to first-order conditions:

$$(3) \qquad x_{i2k} = \frac{\alpha_{2k} \, r_{ik}}{w_2} \quad , \quad \text{for } k = 1, \ldots, K;$$

where r_{ik} = revenue received by the ith grower for the kth crop.

These expressions are used to form the following system:

$$(4) \qquad x_{i2} = \sum_{k=1}^{K} \alpha_{2k} \frac{r_{ik}}{w_2} + \epsilon_{i2}^{x}$$

$$(5) \qquad \ln y_{ik} = \alpha_{1k} \ln x_{i1k} + \alpha_{2k} \ln \frac{r_{ik}}{w_2} + \alpha_{2k} \ln \alpha_{2k} + \beta_k + \epsilon_{ik}^{y}$$

In equations (4) and (5), marginal value product relationships are substituted for the unobserved water allocations among crops. Equation

(4) is a variable input summation equation, reflecting the fact that water applied to all crops must equal the total amount purchased. An additive error term, ϵ_{i2}^{x}, is included in this equation since actual data will rarely fit this relationship exactly.

Equation (5) represents the crop-specific production functions. These equations are not directly estimable due to the unobservability of expected revenue. This is replaced with actual revenue and a set of appropriate error terms, as described in Just, Zilberman, and Hochman. An intercept term, β_k, is included in Equation 5, as part of the necessary modifications.

Full information estimation of this system is achieved using nonlinear three-stage least squares.

Estimated Production Functions

Broadview farm-level data on crop acreages, yields, revenues, and aggregate water use and expenditure for the period 1962 to 1986 are analyzed. Production functions are estimated for the major crops grown in the district during each of the four periods described above. Irrigation water and land are the two inputs considered. Constant returns to scale are imposed on the estimated relationships.

Estimated regression parameters for five crops grown in all four time periods are presented in Table 5. Plots of the estimated functions appear in Figures 2a through 2e.

The barley function does not shift significantly between any of the four time periods, as indicated by the shift F-statistics. The estimated water elasticity for 1983 to 1986, 0.324, is highest of the periods examined. Barley is grown least frequently during these years, resulting in a low number of observations for this crop.

The estimated cotton production function shifts significantly outward between the third and fourth periods. Both the constant term and the water elasticity are higher in the final period than in the previous one.

The estimated production function for sugarbeets shifts outward between the first and second periods, while remaining movements are not statistically significant. The number of observations used to estimate the sugarbeet function is smallest of the five crops examined, in the first three periods.

The tomato and alfalfa seed production functions display similar shifts, over time. Both curves shift inward from the first period through the third, before shifting outward in the final years. The initial shift of the alfalfa seed function is not statistically significant, but all other shifts of these functions do provide better explanation of yield variability than does a single function for any two of the time periods.

Estimated production functions for six additional crops grown during selected time periods are presented in Table 6. The outward shift in the wheat function between the third and fourth periods, though not statistically significant, appears to suggest greater production potential for this crop in the years following installation of the district's drainage outlet (Figure 2f).

In general, the estimated production functions are consistent with changes in yields which have occurred in the water district, over time. Salt-sensitive tomatoes and alfalfa seed production parameters are greatest in the final period, following installation of the drainage outlet. Salt-tolerant cotton and wheat functions are also shifted

outward in this period. Apparent shifts in the barley production function are not statistically significant, but the responsiveness of yields to applied water appears to be greatest in the final period. Similarly, recent shifts in the estimated sugarbeet function are not significant, but the number of observations for this crop is often lowest of those examined.

Estimated Water Application Rates

The amount of water applied per acre, by crop, was not reported in the data. Yet this information is important in evaluating the responsiveness of growers to drainage management alternatives. The estimated water elasticities are used to estimate the unobserved, crop-specific water application rates, using the marginal value product relationship:

$$(9) \quad \hat{x}_{i2k} = \hat{\alpha}_{2k} \frac{r_{ik}}{w_2}$$

where: $\hat{x}_{i2k}$ = estimated irrigation water applied by the ith grower on the kth crop;

$\hat{\alpha}_{2k}$ = estimated water elasticity for the kth crop;

r_{ik} = revenue received by the ith grower for sale of output from the kth crop;

Estimated district average water applications for selected crops are compared with actual district averages available for 1985 and 1986 in Table 7. Estimated water application rates for cotton, sugarbeets, and wheat compare favorably with the actual amounts applied in 1985 and 1986. Similarly, the estimated 3.77 acre feet per acre applied to "other" crops is near the actual 3.75 acre feet applied on corn in 1985 and the 4.18 acre feet applied on beans in 1986. Estimated barley and

alfalfa seed applications are higher than those actually recorded in the two most recent years. The tomato estimate is lower than actual irrigation amounts. The disparity between estimated and actual irrigation rates for barley and tomatoes suggests that additional information would be helpful in estimating production functions for these crops.

Summary

Time-series farm-level data on crop yields, revenues, and aggregate water applications are used to estimate crop-specific production functions for major crops grown in the Broadview Water District. Information from growers and water district personnel is used to describe four time periods during which distinct changes in salinity and drainage conditions have occurred. Significant shifts in the production relationship are identified for both salt-tolerant and salt-sensitive crops. The estimated functions are consistent with observed changes in average yields in the district, over time.

Unobserved water applications, by crop, are estimated and compared with actual irrigation rates for the two most recent years. Estimates compare favorably with actual applications for three of the six crops examined. Additional field-specific and crop-specific data will be useful in obtaining more accurate estimates of irrigation and production relationships.

Two efforts designed to collect information which will enhance the appropriateness and accuracy of the empirical analysis are described in the following sections of the report. These are interviews with Broadview growers and collection of field-specific soil data.

3. Grower Interviews

Eight of the fourteen growers who operate farms in the Broadview Water District were interviewed in August, 1987, using an ethnographic interview format. These eight growers farm about 6,930 acres, or approximately 73 percent of the total irrigated acreage in the district. The ethnographic interview technique is designed to elicit growers' resource taxonomies, in their own words. The effects which individual elements in any taxonomy have on farm-level allocation decisions are then assessed. Within this methodology, it is assumed that (1) growers allocate resources based on their individual perceptions of the resources they command, (2) that these perceptions are dynamic and change in response to such factors as increased experience, technological change, new information, and government regulation and policy, and (3) that these perceptions identify the relevant variables in their assumed production relationships and the resource constraints that determine farm-level resource allocation.

The objectives of this research are the following:

1. To gain insights into the nature of on-farm water management in the district. This information will be useful in identifying water management policy options and for predicting grower response to these alternatives.

2. To compare information from growers regarding land characteristics to field-level data obtained from soil sampling and laboratory analysis. This will assist in improving the efficiency of collecting information on drainage problems and the consequences of water management policies.

3. To provide guidance for any further surveys of a wider geographical area.

Information provided by growers is summarized and discussed below in the context of farm management considerations. These include land quality,

crop rotations, pre-irrigation, drainage system performance, and grower experience.

Land Quality

Information detailing some of the characteristics of quarter sections operated by growers interviewed during the survey reveals several important points. It is apparent that individual quarter sections are the primary management units for most of the farmers in the district. Growers identify a set of characteristics describing each quarter section of land (or smaller units, in the case of some irregular holdings on the border of the district). These determine the manner in which they will manage the land in order to grow a particular crop. In those few instances where quarter sections are divided into smaller units, land characteristics, such as large sand lenses or salt problems, seem to be the basis for the division.

The soil categories--heavy clay, light clay, sandy and so on-- are a subjective judgement on the part of the grower and are recorded here in the growers' terminology. Soil taxonomies are of interest to the extent that soil differences affect management decisions. It is apparent from growers' comments that soil type, as defined by them, is important in determining water application strategies and in controlling salt build-up. Heaviness of the soil, for example, affects the timing of pre-irrigation in cotton. Heavy soils with poor internal drainage must be pre-irrigated during the fall or winter months if the fields are to be dry enough in the spring to permit timely planting of the crop.

Based on our consideration of the survey data to date, it appears that each quarter section, or in some cases a smaller field, is viewed by the grower as having crop production possibilities based on its water

holding characteristics and its salt content at any point in time. Salt content is a function of the quality and quantity of irrigation water that has been applied in the past and the drainage characteristics of the fields. These, in turn, are considered to be determined by the basic soil, the field's location, slope and water table (all of which influence drainage), and are subject to control by the addition of gypsum as a soil amendment and the installation of drainage tiles. The effectiveness of the drainage tile is considered to be determined by the depth and density of the tiles and the precision with which the system was installed.

Crop Rotations

The particular field circumstances, along with the usual factors such as government programs (eg. acreage set aside), the availability of contracts with processors, and prices determine the crops which the grower chooses to grow. The capacity to control water in order to achieve the desired field conditions deemed favorable for plant growth, is considered by growers to be more important than all other factors, in achieving high yields and net returns.

There is widespread concern among growers regarding soil quality. All of the growers who were interviewed expressed some concern over managing their fields in a way that maintains desirable soil conditions. Some growers keep wheat in their crop rotation, even though they feel it is not the crop which will maximize profits, at current prices. The value of wheat in a crop rotation is that the crop residue contributes to soil fertility and conditioning, and thus improves the yields of subsequent crops. In other words, growing wheat is a cost of the production of other crops. Chicken manure and gypsum are seen as soil

improvement materials. A number of growers have regular programs for incorporating these additives.

It is clear that salts play an important role in determining the growers' crop rotations. Tomatoes are known as a particularly salt-sensitive crop, although the availability of contracts with canneries also acts to restrict tomato acreage. Sugarbeets, on the other hand, perform well on salty ground but have a high crop water requirement (up to five acre feet per acre, to mature a crop).

Pre-irrigation

Pre-irrigation is important in controlling salinity and in providing water for establishing the crop. The amount of water applied and the timing of pre-irrigation depend on the field circumstances and the crop to be grown. For example, wheat is generally planted in late fall/early winter with no pre-irrigation. Similarly, alfalfa seed, and sometimes tomatoes, are brought up on rainfall.

There is considerable variation in the timing of pre-irrigation for cotton. Some growers pre-irrigate in late fall/early winter. Two rationales are given for this practice. One grower, whose fields are near the end of the district's distribution system, pre-irrigates early because competition for water is minimal at this time of year and also because the quality of the water is better than during later months. This is because the percentage of re-circulated subsurface water in the system is low at this time of year. Other growers pre-irrigate early because their soils are such that if they wait until later in the season, the fields will not be dry enough to move in the equipment for spring planting. This is typically an important consideration on the heavier clay soils and those with a salt problem, where it is difficult

to get water to move into the soil profile. Delaying pre-irrigation to the early spring is not an option available to growers faced with these circumstances.

In general, growers recognize the potential utility of sprinkler systems for the first irrigation on cotton in the spring, and for irrigating-up other spring-planted crops. Growers are not in agreement, however, that the water savings and the benefits to the crop will justify the necessary investment. Growers see sprinkling as a good way to avoid salt accumulation in the seed beds when furrow irrigation is used for pre-irrigating. With sprinklers, the salts are dispersed during the first irrigation, to the benefit of the plant. For subsequent irrigations on crops such as cotton, furrows are considered the appropriate technique.

Drainage

One important constraint to crop production and to water management and conservation, according to growers, is the presence and adequate performance of tile drainage systems. Several growers are not satisfied with the effectiveness of their tile drains and blame faulty design and/or installation. Some growers suggest that improvements in drainage conditions would result in reduced water applied during pre-irrigation. Overall, water management, including both field application and drainage, appears to have an importance to the growers which is greater than that of any other production input.

Grower Experience

One general impression of agricultural production in the Broadview Water District is that each of the farmers has developed, over time, a production system which is sensitive to the constraints encountered in

their fields, and which also includes the grower's preferences for crops with which they have been successful. For example, there have been only three farmers in the district over the last several decades who have been alfalfa seed growers. Currently there are two, and each speaks to the difficulties of managing the crop for high production levels. They suggest that it requires a specialized knowledge.

Other examples of growers' preferences include statements such as, "I don't grow tomatoes because I don't want to go broke," or "I can do good at small grains, but there is no money in them," or "I like to grow melons," or "Really, we are primarily rice growers," and so on. In other words, the enterprise combinations that one finds on a given farm are the result of the grower's total experience with working that farm. This experience includes successes, prejudices, and preferences. A set of selected grower comments describing many aspects of grower experiences are presented in Appendix 1.

Summary

Of special interest to this study are the water conservation techniques that have been adopted by growers in the Broadview Water District. To date, our analysis of the data does not allow identification of these different practices with the cultivation of different crops under different soil and salt conditions. However, the hypothesis at this time is that there is a relationship between water management practices, crops, and soils. The following observations are relevant to the water management issue:

1. Almost all of the Broadview growers use quarter-mile runs for pre-irrigation.
2. Growers have been experimenting with different irrigation strategies on cotton, including irrigating in alternate furrows

and changing the time-length of irrigation sets as a means of conserving water.

3. Sprinkler irrigation is viewed as a way of dealing with salt accumulations in the seed rows and of conserving water. Growers have different opinions as to the economics of sprinkler irrigation on the different crops and soil situations in the district.

4. Several growers have inadequate drainage systems. In their opinion, this results in increased amounts of water used for pre-irrigation.

5. Neither gated pipe nor surge irrigation has taken hold in the Broadview Water District. One grower, interviewed from a neighboring district, is using "manual surge" to reduce irrigation water applications. He feels this technique is effective in reducing both tailwater and subsurface drainage.

6. The strategy for pre-irrigating cotton is definitely a function of the soil and salt conditions encountered by individual growers.

Further analysis of the information gathered from grower interviews will include a comparison of measured physical characteristics with problem areas identified by the growers. Also, farm-level data will be used to identify appropriate variables and resource constraints for use in analysis of production relationships.

A description of the soils data collection procedure and some preliminary analysis are presented in the following section.

4. Soils Data Collection and Analysis

The agricultural drainage problem in the San Joaquin Valley and elsewhere arises from the need to leach accumulated salts from the soil profile. During the leaching and drainage process, these salts and other constituents are moved through the soil and into receiving pipes or ditches. Soil quality takes on a dual role in farm-level drainage management, as a result of environmental concerns regarding drain water quality.

The level of nutrients, salts, and metals in agricultural soils affects plant growth and productivity. Farmers strive to maintain optimal levels of these soil constituents, in order to achieve profitable yields. The level of various materials in soils may also determine the quality of drainage water produced from a farm operation. There may also be an empirical relationship between the amount of leaching water applied to the soil profile and the quantity and quality of subsurface drainage water generated.

Efforts by growers to modify the quantity or quality of subsurface drainage water leaving the farm will likely result in changes in soil quality. These changes may affect crop yields and the quality of drainage water produced in the future. Accurate description of relationships between soil quality, yields, and subsurface drainage water quality is necessary to fully describe potential farm-level responses to drainage management policies.

Soils data are collected in this study for two purposes: 1) to enhance the production function analysis presented in the second part of this report, and 2) to examine empirical relationships between farm-level irrigation strategies and the quantity and quality of drainage

water produced. These efforts will improve the pertinence and validity of any recommendations which arise from the study.

Methodology

Soil samples were collected from agricultural fields in the Broadview Water District during the summer of 1987. Most of the fields are 160-acre quarter-sections of land and are planted to a single crop. Some fields are smaller than 160 acres and others are planted to two crops, or to one crop and a fallow area. In the 160-acre fields, five soil samples are collected along each of four east-west transects. These twenty samples include material from the top three feet of the soil profile. One additional sample is taken from three to six feet deep, at a location near the corner of the field.

Soil salinity is measured during the data collection effort with an electromagnetic conductivity meter (EM-38). This hand-held device is carried throughout the fields and readings are taken at each of the twenty sites. Both horizontal and vertical readings are taken, in order to characterize soil salinity from a depth of zero to 6 feet. An additional measurement is taken at the site where the 3 to 6 foot soil sample is gathered.

The electromagnetic meter has been shown to generate reliable soil salinity measurements when used in conjunction with laboratory analysis of selected soil samples (Corwin and Rhoades, Rhoades, Rhoades and Corwin). The meter may become a useful tool for growers or water district personnel interested in monitoring soil salinities under different irrigation and drainage strategies.

Four of the individual soil samples are sent directly to the laboratory for chemical analysis. These include samples from locations

which have the two highest EM readings and the lowest EM reading. The sample taken from the 3 to 6 foot depth is also sent directly to the lab. Five additional samples are prepared by combining soil from some of the individual sites, to form composite samples. Four of these are prepared by combining soil from the five samples taken along each transect, to form a single sample representing the transect. The final composite sample is made by combining soil from each of the twenty sites in the field.

This procedure for collecting and preparing soil samples is the same for fields which are smaller than 160 acres, but the number and length of transects in the field varies with the acreage.

All of the nine samples sent to the laboratory from each field receive standard agricultural nutrient analysis. This "routine" analysis includes measurement of soil pH, electrical conductivity, sodium adsorption ratio, organic matter content, and nitrate nitrogen. Plant available extract measurements (AB-DTPA) are made for phosphorous, potassium, zinc, iron, manganese, copper, lead, cadmium, nickel, molybdenum, and chromium. Calcium, magnesium, sodium, potassium, chloride, and boron are measured in the saturated extract.

Three of the samples from each field receive research soil analysis. This "detailed" analysis includes total digest measurement (HNO_3-$HClO_4$) of arsenic, selenium, copper, zinc, nickel, molybdenum, cadmium, chromium, and lead. The total amount of mercury is also measured for these samples.

All of the soils analysis for this project is performed by the Colorado State University Soil Testing Lab in Fort Collins, Colorado. This laboratory was chosen because of its good reputation in testing for

selenium and other elements. A report on quality control at the CSU Lab is presented in Appendix 2.

Soil test results for 48 of the sampled fields have been received, as of this writing. These results are analyzed from two perspectives which are pertinent to the overall project objectives. First, the average levels of salt, selenium, and other elements in the soil samples are examined. This provides an indication of the variability which exists among fields in the water district. This information is useful in describing the effects of different drainage scenarios, over time, and may be helpful in predicting concentrations of subsurface drainage flows.

The variability of salinity levels within a given field is also examined. This information will be helpful in developing better models of yield responses to saline conditions. Crop fields in the water district are large and soil conditions may vary widely within one field. Salinity is believed to affect crop yields when a threshold level of salts has been exceeded (Maas and Hoffman). Given this framework, it is possible that a field with an average soil salinity which is below the threshold level may still show a yield effect, if some areas of the field exceed the threshold level.

Soil salinity, sodium adsorption ratio, and boron

The average levels and the variation of soil salinity and other constituents are examined by constructing weighted averages of the eight measurements from the top three feet of soil, in each field. The weights are determined by the type of sample taken. For example, a soil sample from an individual site is given a weight of 20, while a composite sample made up of soil from five sites along a transect is

given a weight of 4. The composite sample which is comprised of soil material from all of the 20 individual sites receives a weight of 1.

Weighted averages and other summary statistics are computed for each of the 48 fields. These results are summarized in Table 8. The soil pH varies least among the fields examined. The average pH in the district is 7.96 and the standard deviation is just 0.17. This results in a coefficient of variation of only 2.2.

The weighted average soil salinity ranges from a low of 1.28 millimhos per centimeter in one field to a high of 8.45 in another. The mean value for the 48 fields is 4.03 millimhos per centimeter and the standard deviation is 1.96. The coefficient of variation for the mean salinity level is 48.7. The sodium adsorption ratio (SAR) and the amount of boron in the soil samples display similar variability. For example, the mean SAR varies from a low of 4.00 in one field to a high of 17.03 in another. The average of the weighted SAR's is 8.15 and the coefficient of variation is 37.6. Average boron levels range between 0.88 and 5.49 milligrams per liter, with a mean value of 2.29 milligrams and a coefficient of variation of 49.1.

Variation within farm fields is evaluated by examining summary statistics for the coefficients of variation which are calculated for each field. For example, the coefficients of variation describing soil pH range from 0.3 to 3.2, with a mean value of 1.1. This suggests that there is little variation in soil pH within fields. The coefficients of variation describing soil salinity, SAR, and boron display a much wider range of values. Some fields appear to be quite uniform, as indicated by the minimum values of 5.7, 4.4, and 11.2. At the same time, other fields appear quite variable, as suggested by maximum values of 70.2,

82.6, and 93.8. The mean values of the coefficients of variation are 33.7, 30.9, and 37.5 for soil salinity, SAR, and boron.

Fields which are high in soil salinity tend to be high in boron and also tend to have a high sodium adsorption ratio. This is suggested by the correlation coefficients calculated for weighted averages of the soil samples (Table 9). The correlation coefficients for the means of soil salinity, SAR, and boron are all positive and statistically significant. Results also suggest that fields which have high levels of salt, SAR, and boron tend to have greater variability in these measurements. That is, fields with a high average salinity level tend to be less uniform than fields with lower average salinity. The same is true for SAR and boron. Furthermore, non-uniformity in salinity is positively correlated with non-uniformity in SAR and non-uniformity in boron.

Selenium

The high cost of measuring selenium in soil samples has limited its measurement to just three of the nine samples per field which are sent to the laboratory. The first sample is a composite made up of some soil from each of the 20 sampling sites. The second sample is the one taken at the location indicating the highest salinity level in the field, as measured with the electromagnetic meter. The third sample which is analyzed for selenium is the one taken from the three to six foot soil depth. Summary statistics are presented for each of these three samples. Results for selenium are compared with those for salinity, boron, and the sodium adsorption ratio for these same samples.

The average level of selenium in the composite soil samples is 1.58 parts per million (Table 10). The coefficient of variation for selenium in these samples is 23.4. The coefficients of variation for salinity,

SAR, and boron are 43.0, 35.9, and 44.3. This suggests that selenium is less variable in these samples than is salinity, SAR, or boron.[1]

The mean level of selenium measured in samples collected at sites indicating high salinity is 1.73 parts per million and the coefficient of variation is 35.0 (Table 11). The coefficients of variation for salinity, SAR, and boron are 55.7, 48.2, and 55.2 for these samples.

The average level of selenium in samples taken from the 3-6 foot depth is 1.3 parts per million and the coefficient of variation is 27.4 (Table 12). Again, the variability of selenium in these samples is less than that for salinity, SAR, or boron. The mean level of selenium in the deep samples is less than that of selenium in the composite samples taken from the 0-3 foot depth, as seen by comparing results in Table 5 with those in Table 10. This is not the case for salinity, SAR, and boron. These three measurements have a higher mean value, occur over a wider range, and are more variable in the deep samples, than in the composite samples from the 0-3 foot depth. These preliminary results suggest that while salts and boron may be leached from the upper three feet into the lower portion of the soil profile, total selenium may be greater in the top three feet than in the 3-6 foot range.

Correlation coefficients for soil salinity, SAR, boron, and selenium are presented in Table 13. Salinity appears to be negatively correlated

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1. Selenium is measured as total selenium in an HNO_3-$HClO_4$ digest, while boron and the SAR are measured in the saturation extract. Soil salinity is measured in the saturated paste. These differences may affect measures of relative variability.

with soil pH in both the composite and high salinity samples. The sodium adsorption ratio and boron are both positively correlated with soil salinity in all three types of samples. Total selenium is not significantly correlated with salinity in either the composite samples or those taken from the 3-6 foot depth. There is a positive and significant correlation between soil salinity and total selenium in the samples taken from the high salinity locations.

Electromagnetic Meter Measurements

Soil conductivity measurements are made at each of the 20 soil sampling sites in every field, using a hand-held electromagnetic meter. These measurements will be correlated with the soil salinity data received from the laboratory to determine a calibration which will allow rapid and accurate evaluation of soil salinity in the field.

The variability of readings obtained with the electromagnetic meter is similar to that observed in the laboratory data. For example, the average of 20 horizontal mode readings per field ranges from a low of 96 millimhos per meter to 394 millimhos per meter, with a mean value of 235 millimhos (Table 14). The coefficient of variation is 31.6, suggesting moderate variability among fields. Vertical mode measurements display similar variation.

The coefficients of variation for the twenty horizontal mode readings per field range from a low of 5.9 to a high of 41.7. The vertical mode readings are very similar. These results suggest that some fields generate very uniform electromagnetic readings, while others result in a more variable set of measurements. Uniformity in electromagnetic readings is likely correlated with uniformity in soil test results from the laboratory.

Summary

Soil samples collected from 48 agricultural fields in the Broadview Water District during the summer of 1987 have been analyzed for nutrients, salts, metals, and selenium. Average soil salinities range from a low of 1.3 millimhos per centimeter to a high of 8.4 millimhos. Coefficients of variation in individual fields range from 5.7 to 70.2. Similar ranges and variability are observed for boron and the sodium adsorption ratio. These results suggest that both average levels and variability in soil salinity and other constituents may be important in constructing farm-level crop production models.

Fields which are high in soil salinity tend to be high in boron and have a high sodium adsorption ratio. High salinity fields are also more variable than those which are low in salinity.

The average selenium level measured in soil samples from zero to three feet deep is 1.6 parts per million. The average selenium level in samples indicating a high soil salinity is 1.7 parts per million and the average level in deep soil samples is 1.3 parts per million. The total amount of selenium in soil samples is less variable than soil salinity measurements. Total selenium levels are not correlated with soil salinity measurements in composite samples or those collected from three to six feet deep.

Measurements of apparent bulk soil conductivity with a hand-held electromagnetic meter display variability similar to that observed for soil electrical conductivity, as measured in the saturation extract. Variability within fields is likely correlated with uniformity in soil test results from the laboratory.

The soils data collected in this study will be used to enhance production function analysis and to examine empirical relationships between farm-level irrigation strategies and the quantity and quality of drain water produced. These and other current efforts in our economic analysis of farm-level irrigation and drainage management are discussed in the following section.

5. Current Efforts and Future Work

The objectives of this research, as described in Section 1, include examination of farm-level cultural practices in areas with salinity and drainage problems. Production parameters are being estimated from farm-level data on soil salinity, irrigation rates, crop yields, and other important variables. A farm-level optimization model is being developed and will include irrigation and recycling opportunities pertinent to typical farming operations in the San Joaquin Valley.

Several of the research activities described in the first four sections of this report represent continuing efforts to develop a data base for use in analysis of farm-level drainage management and in analyzing the economic impacts of salinity and high water tables on growers in drainage problem areas. These efforts, combined with data collection and analysis planned for the coming year, will allow more accurate prediction and description of farm-level responses to policies designed to regulate the quantity or quality of subsurface flows from farms or water districts.

Activities

In particular, future research efforts will include four major tasks:

1. Economic analysis of farm-level decisions regarding optimal management of soil salinity and drainage water in the San Joaquin Valley.

2. Estimation of crop-specific production functions for use in a regional agricultural production model.

3. Cooperation with other Drainage Program researchers in examining factors which influence the choice of irrigation and drainage technologies at the farm level. Specific activities in this task will be determined during discussions with cooperating researchers.

4. Relevant data collection activities.

The farm-level optimization model will consist of three major components:

a. Yield relationships describing crop production as a function of applied irrigation water and soil salinity.

b. Physical relationships describing the movement of salt through the soil profile and into drainage and recycling systems.

c. Water quality relationships describing the salt content of water at various stages in the system, including surface runoff, subsurface drainage, drain water disposed, and drain water used in recycling.

The farm-level objective function specified in the model will be the maximization of economic returns to land, management, and fixed resources, over time.

Several drain water disposal scenarios will be examined using the optimization model. These will include unconstrained drainage disposal, in which case growers are able to choose recycling and disposal rates, independent of restrictions on drain water leaving the farm. By comparison, quality and quantity constraints on drain water disposal will also be examined. Results of this analysis will describe the economic impacts which potential constraints may have on the production of major crops. Optimal leaching and disposal rates will be determined for all scenarios examined.

Coefficients for use in the regional production model will be developed using soils data and other information collected from the Broadview Water District. These data will be combined with crop report and water delivery data to estimate production functions for major crops grown in the district. Estimated functions will be included as key physical relationships in the farm-level optimization model. Parameters

will also be useful in a regional agricultural production model which is based on soils classification data.

Both the average level of salinity in crop fields and the variability of soil salinity will be used as explanatory variables in the production functions.

Data collection efforts in support of the tasks described above, will include the following activities:

a. Collection of water quality data from a set of farm sumps, including measurement of electrical conductivity, boron, and selenium.

b. Collection of field-specific soil salinity data with an electromagnetic meter and analyze selected soil samples for moisture content, salinity, and other constituents.

c. Collection of calibration data for use in converting soil salinity data, as measured with an electromagnetic meter, to estimates of electrical conductivity in the saturated extract.

d. Collection, in conjunction with other Drainage Program researchers, of data describing factors which may influence the choice of irrigation and drainage technologies by growers in the San Joaquin Valley.

Discussion

The soil and water quality data collected during the project will be used to enhance estimates of crop-specific production functions. Information on average levels of salinity, SAR, and boron will be included in the estimated relationships. The variability of these measurements within fields will also be included. The amount of variation in soil salinity and other elements likely reflects the effects of poor drainage and/or non-uniform water applications, over time. Inclusion of these measurements in the production function analysis will provide more accurate estimates of the relationship between crop yields, applied water, and soil quality.

Additional information on yields and cropping patterns will be important in updating and further analyzing the economic impacts of salinity and high water tables. Field-specific yield data are being collected for crop year 1987. This detail has not been available in the past. Yields will be examined for correlations with soil quality and cultural practices.

One of the cultural practices receiving much attention in discussions regarding reductions in subsurface flows is pre-irrigation. Information obtained during grower interviews has revealed many of the economic considerations which determine the amount and timing of water applied during winter months. These management concerns need to be incorporated in analysis of farm-level responsiveness to changes in drainage situations.

Field-specific data on the amounts and timing of pre-irrigations will allow better description of the farm-level economic considerations involved in changing this cultural practice. To date, water use data has included only the total amount of water applied to crops. The different yield effects of water applied during pre-irrigations and that applied during the growing season can be examined only by collecting field-specific data on pre-irrigations.

Growers have indicated that some changes in cultural practices designed to conserve applied water have already been implemented in their farming operations. The motivation behind these changes is the economics of crop production. The value of changing the length of irrigation runs or irrigating in alternate furrows can be evaluated by examining the changes in water use rates and any resulting yield

effects. Field-specific data on cultural practices, water use, and yields will allow this analysis to be performed.

Field-specific data on the quality and quantity of subsurface flows is essential to economic analysis of farm-level responsiveness to changes in drainage situations. Changes in cultural practices designed to reduce applied water and subsurface flows are not costless. Growers will implement these changes only when economic advantages to doing so are apparent. Hence, the relationship between changes in applied water and the resulting subsurface flows needs to be accurately quantified.

The relationship between changes in these flows and the resulting concentrations and loads of salt and other elements needs to described in a way which is pertinent to farm-level operations. The data collected in this project include field-level subsurface flows and concentrations of salt, selenium, and other constituents. This information can be used to accurately predict the farm-level potential for changing loads of specific elements.

Empirical analysis of the relationship between flows and loads complements the production function analysis. Yield effects of changes in applied water or changes in application strategies can be evaluated along with the predicted effects upon quality and quantity of drainage water generated. These are precisely the tradeoffs which growers will be faced with, in reponse to any changes in drainage situations. A complete economic analysis of farm-level drainage management needs to include both yield effects of changes in cultural practices and the subsurface flow effects (both quality and quantity) of these changes.

Changes in surface runoff (tailwater), as a result of changes in farm-level cultural practices also need to be evaluated. Tailwater has

economic values both in re-circulating for use in crop irrigation and in dilution of subsurface drain water, in areas where an outflow quality constraint may be placed on agricultural drainage water. The magnitude of these two values will be determined by relative prices for irrigation water and the costs of treating or reducing subsurface flows. Information describing relationships between changes in cultural practices, the quality and quantity or subsurface flows, and the quantity of tailwater produced will be useful to both farmers and water district managers.

Summary

Economic analysis of farm-level responsiveness to changes in drainage situations requires information on crop yields, cultural practices, soil quality, and the quality and quantity of subsurface flows and tailwater. When recommendations are made to growers or water district managers regarding changes in cultural practices to modify the quality or quantity of subsurface drainage water, it will be necessary to include estimates of the farm-level economic impacts of these changes. This will require describing to farmers, and others, the estimated costs of implementing various proposed alternatives and the likely farm-level benefits of these changes. These benefits will include predicted changes in the quality and quantity of subsurface flows. Empirical analysis of the various aspects of farm-level drainage management described in this report will enhance the accuracy and validity of these predictions and the associated recommendations.

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Table 1. Weighted average yields per acre for selected crops in the Broadview Water District and Fresno County, by time period, 1982 through 1986

	Cotton		Tomatoes		Alfalfa Seed		Barley		Wheat		Sugarbeets	
Period	BWD	FC	BWD	FC	BWD	FC	BWD	FC	BWD	FC	BWD	FC
	(Bales)		(Tons)		(Pounds)		(Tons)		(Tons)		(Tons)	
1982-1970	2.4	2.2	30.3	20.5	776	n/a	1.9	1.8	1.9	1.8	20.8	20.4
1971-1977	2.2	1.9	28.8	24.7	743	560	2.2	1.8	2.2	1.9	30.2	25.0
1978-1982	2.3	2.1	19.3	28.3	601	530	1.8	1.7	2.8	2.5	25.5	27.2
1983-1986	2.8	2.5	34.8	31.2	938	711	2.4	1.8	3.2	2.8	30.1	30.0

Table 2. Average per-acre revenues from crop production in Broadview Water District and Fresno County, by time period, 1962 through 1988

	Cotton		Tomatoes		Alfalfa Seed		Barley		Wheat		Sugarbeets	
Period	BWD	FC	BWD	FC	BWD	FC	BWD	FC	BWD	FC	BWD	FC
						(Total Revenue per Acre)						
1962-1970	403	338	954	808	295	n/a	88	77	98	87	254	258
1971-1977	486	420	1,092	1,032	528	414	177	144	256	178	820	801
1978-1982	782	665	1,004	1,513	825	825	166	187	345	307	771	834
1983-1988	886	816	1,798	1,823	779	747	287	201	393	337	1,039	1,008

Table 3. Increases in average per-acre yields between the third and fourth time periods, Broadview Water District and Fresno County

Crop	Broadview		Fresno County	
	Actual	Percent	Actual	Percent
Cotton	0.3 Bales	13.0	0.4 Bales	19.0
Tomatoes	15.5 Tons	80.3	2.9 Tons	10.2
Alfalfa Seed	337.0 Pounds	56.1	181.0 Pounds	34.2
Barley	0.6 Tons	33.3	0.1 Tons	5.9
Wheat	0.6 Tons	23.1	0.3 Tons	12.0
Sugarbeets	4.6 Tons	18.0	2.8 Tons	10.3

Note: The third time period includes years 1978 through 1982 and the fourth period includes 1983 through 1986.

Table 4. Estimated value of yield improvements following installation of a drainage outlet in the Broadview Water District

Crop	Estimated Maximum Yield Increase due To Improvement in Soil and Water Conditions	Value of the Yield Increase at Average Nominal Prices for the period 1983 to 1986
	(Yield per Acre)	(Dollars per acre)
Tomatoes	13.5 Tons	698
Alfalfa Seed	131.0 Pounds	109
Barley	0.5 Tons	60
Wheat	0.3 Tons	37
Sugarbeets	2.0 Tons	69

Table 5. Estimated Cobb-Douglas production functions for major crops grown in the Broadview Water District, 1962-1986

Crop	Time Period	Number of Obs.	R-Squared	Constant Term	Water Elasticity	Shift F-Statistic
				(β_k)	(α_{2k})	
Barley	62 - 70	84	.95	.582	.120	
	71 - 76	20	.89	.770	.034*	
	77 - 82	16	.46	.264*	.293	1.52
	83 - 86	6	.89	.426*	.324	.39
Cotton	62 - 70	100	.92	.725	.093	
	71 - 76	60	.87	.714	.027	12.05
	77 - 82	81	.84	.735	.067	2.96
	83 - 86	43	.93	.847	.086	3.60
Sugarbeet	62 - 70	14	.83	2.785	.166	
	71 - 76	14	.93	3.275	.095	4.09
	77 - 82	5	.85	2.686	.239	.02
	83 - 86	12	.85	3.049	.164	.38
Tomatoes	62 - 70	19	.94	3.339	.030	
	71 - 76	43	.80	3.163	.032	5.06
	77 - 82	19	.54	2.845	.029	4.18
	83 - 86	11	.74	3.490	.033	12.95
Alfalfa Seed	62 - 70	71	.89	1.850	.082	
	71 - 76	42	.75	1.734	.104	
	77 - 82	22	.56	1.594	.067	3.38
	83 - 86	8	.89	2.056	.108	4.76

Note: The superscript * indicates that the estimated parameter is not statistically significant at the five percent level.

The shift F-statistic pertains to the current and previous period models.

Table 6. Estimated Cobb-Douglas production functions for selected crops grown in the Broadview Water District, 1962-1986

Crop	Time Period	Number of Obs.	R-Squared	Constant Term	Water Elasticity	Shift F-Statistic
				(β_k)	(α_{2k})	
Milo	62 - 70	25	.94	.419	.199	
Safflower	62 - 70	12	.84	.725	.093	
Alfalfa Hay	62 - 70	8	.81	1.449	.140	
Melons	62 - 70	36	.86	5.218	.023	
Dry Beans	77 - 82	11	.92	2.953	.103	
Wheat	77 - 82	17	.82	.557	.283	
	83 - 86	21	.95	.989	.169	1.88

Note: The superscript * indicates that the estimated parameter is not statistically significant at the five percent level.

The shift F-statistic pertains to the current and previous period models.

Table 7. Actual and estimated water application rates for selected crops in the Broadview Water District, 1983-1986

Crop	Actual Average Water Application Rate 1985		Actual Average Water Application Rate 1986		Estimated Average Water Application Rate 1983 through 1986	
Barley	1.91	(4)	1.85	(1)	3.38	(6)
Cotton	3.17	(28)	3.06	(31)	3.10	(42)
Sugarbeets	5.79	(5)	4.43	(3)	5.73	(12)
Wheat	3.28	(9)	1.92	(8)	2.68	(21)
Melons	2.49	(6)	2.09	(5)		
Tomatoes	3.79	(5)	3.10	(5)	2.60	(11)
Alfalfa Seed	2.16	(4)	2.66	(5)	3.50	(8)
Alfalfa Hay	3.49	(2)	2.56	(2)		
Corn	3.75	(1)				
Dry Beans			4.18	(1)		
Others					3.77	(16)

Note: The value in parentheses is the number of observations from which the average application rate is calculated.

Table 8. Summary statistics for weighted averages of soil samples collected from 20 sites in each field at a zero to three foot depth, Broadview Water District, summer 1987

Item (units)	Number of Obs.	Mean	Standard Deviation	Minimum Value	Maximum Value	Coefficient of Variation
Means						
Soil pH	48	7.96	0.17	7.41	8.29	2.2
Soil EC (mmhos/cm)	48	4.03	1.96	1.28	8.45	48.7
SAR	48	8.15	3.07	4.00	17.03	37.6
Boron (mg/l)	48	2.29	1.12	0.88	5.49	49.1
Coefficients of Variation						
Soil pH	48	1.1	0.7	0.3	3.2	64.8
Soil EC	48	33.7	16.7	5.7	70.2	49.3
SAR	48	30.9	16.7	4.4	82.6	53.9
Boron	48	37.5	16.0	11.2	93.8	42.6

Notes: SAR is the sodium adsorption ratio.

Boron is measured as milligrams per liter in the saturation extract.

Selenium is measured as parts per million of total selenium in an HNO_3-$HClO_4$ digest.

Table 9. Pearson correlation coefficients for weighted averages of soil samples collected in the Broadview Water District, summer 1987

	Mean EC	Mean SAR	Mean Boron	CV EC	CV SAR	CV Boron
Mean EC		.63**	.83**	.48**	.60**	.41**
Mean SAR			.85**	.51**	.34**	.24*
Mean Boron				.56**	.56**	.45**
CV EC					.53**	.52**
CV SAR						.73**
CV Boron						

Notes: SAR is the sodium adsorption ratio.

The superscript ** indicates that the correlation coefficient is significantly different from zero at the 5-percent level and the superscript * indicates significance at the 10-percent level.

Table 10. Summary statistics for composite soil samples collected from 20 sites in each field at a zero to three foot depth, Broadview Water District, one composite sample per field, summer 1987

Item (units)	Number of Obs.	Mean	Standard Deviation	Minimum Value	Maximum Value	Coefficient of Variation
Soil pH	30	7.90	0.20	7.30	8.20	2.5
Soil EC (mmhos/cm)	30	4.62	1.98	1.50	7.80	43.0
SAR	30	7.98	2.87	3.50	14.50	35.9
Boron (mg/l)	30	2.39	1.06	0.90	5.00	44.3
Selenium (ppm)	48	1.58	0.37	1.00	3.20	23.4

Notes: SAR is the sodium adsorption ratio.

Boron is measured as milligrams per liter in the saturation extract.

Selenium is measured as parts per million of total selenium in an HNO_3-$HClO_4$ digest.

Table 11. Summary statistics for soil samples collected from zero to three foot depths at locations indicating high soil electrical conductivity, Broadview Water District, one sample per field, summer 1987

Item (units)	Number of Obs.	Mean	Standard Deviation	Minimum Value	Maximum Value	Coefficient of Variation
Soil pH	30	7.97	0.24	7.40	8.40	3.0
Soil EC (mmhos/cm)	30	5.89	3.28	1.40	11.50	55.7
SAR	30	10.98	5.29	1.70	23.50	48.2
Boron (mg/l)	30	3.36	1.86	0.90	8.10	55.2
Selenium (ppm)	48	1.73	0.60	1.05	5.20	35.0

Notes: SAR is the sodium adsorption ratio.

Boron is measured as milligrams per liter in the saturation extract.

Selenium is measured as parts per million of total selenium in an HNO_3-$HClO_4$ digest.

Table 12. Summary statistics for soil samples collected from three to six foot depths in the Broadview Water District, one sample per field, summer 1987

Item (units)	Number of Obs.	Mean	Standard Deviation	Minimum Value	Maximum Value	Coefficient of Variation
Soil pH	44	8.00	0.15	7.50	8.30	1.8
Soil EC (mmhos/cm)	44	5.28	3.33	1.00	14.80	62.9
SAR	44	10.73	6.34	1.11	25.40	59.1
Boron (mg/l)	44	2.65	1.52	0.50	6.50	57.2
Selenium (ppm)	48	1.30	0.36	0.80	2.45	27.4

Notes: SAR is the sodium adsorption ratio.

Boron is measured as milligrams per liter in the saturation extract.

Selenium is measured as parts per million of total selenium in an HNO_3-$HClO_4$ digest.

Table 13. Pearson correlation coefficients for soil samples collected in the Broadview Water District, summer 1987

Correlation With Soil EC	Composite Samples (0 to 3 ft)	High Salinity Samples (0 to 3 ft)	Deep Samples (3 to 6 ft)
Soil pH	-.37**	-.36**	-.18
SAR	.55**	.66**	.87**
Boron	.77**	.87**	.90**
Selenium	.29	.36**	.24

Notes: SAR is the sodium adsorption ratio.

The superscript ** indicates that the correlation coefficient is significantly different from zero at the 5-percent level.

Table 14. Summary statistics for the averages of soil electromagnetic readings, soil moisture depletions, and soil textures measured at 20 sites in each field in the Broadview Water District, summer 1987

Item (units)	Number of Obs.	Mean	Standard Deviation	Minimum Value	Maximum Value	Coefficient of Variation
Means						
Horizontal (mmhos/m)	48	235.0	74.4	96.0	394.0	31.6
Vertical (mmhos/m)	48	280.3	86.1	120.5	489.2	30.7
Soil Moisture Depletion (%)	48	36.2	7.3	17.4	51.6	20.1
Soil Texture (scale)	48	6.0	1.6	1.0	9.4	26.5
Coefficients of Variation						
Horizontal	48	16.6	8.1	5.9	41.7	48.7
Vertical	48	17.4	7.7	8.1	41.6	44.3
Soil Moisture	48	11.5	6.2	3.9	31.6	53.7
Soil Texture	48	19.3	10.4	0.0	58.8	53.8

Notes: Vertical and horizontal measurements describe the apparent conductivity of the ground, in millimhos per meter. The horizontal mode measures conductivity in the top three feet of soil, while the vertical mode measures conductivity in the top six feet of soil.

The soil texture scale assigns a value of 1 to clay, 4 to clay loam, 7 to loam, 10 to sand, and 12 to silt. Intermediate values are assigned to other classifications on the soil triangle. For example, silty clay loam is given a value of 6.

Appendix 1

Selected Comments By Growers in the Broadview Water District

Provided During Interviews

August 1987

GROWER A

Likes to pre-irrigate in October because the quality of the water is better in this month and because there "is no re-circulated subsurface water in the system." Tries to push the salts down and keep other people from pushing water up on him. So, he pre-irrigates in October, shortly after ripping; "the ground is open and water goes down faster."

Summer water is saltier.

On field 1, can't let weed pressure get too great or allow the ground to crack--"you'll be short of moisture when ready to plant."

There has been difficulty with the tile system in field 1. The system was dug up two years ago to see what the problem might be, and they found that the tile had been laid in the clay rather than in the gravel; i.e., it looked like a bad installation. "The system just doesn't put out." The operator ties to get as much pre-irrigation water as possible to make allowance for the poor tile system. The strategy is to try to push in about 12 inches in the pre-irrigation, "so that when upslope people irrigate, the water won't come down from above." The current notion is that with better drainage tile, the pre-irrigation amount could be cut back to about 6 inches.

Pre-irrigation is known to push salts up into the beds when prepared for cotton. "Some years, when you don't get rain, salts on the top of the cotton bed look like snow."

Last year, on field 1, an effort was made to improve the drainage while the leveling operation was going on, by applying three tons of gypsum and four tons of chicken manure in rice hulls. They even doubled up on the bad spots, but these practices did not seem to make any difference.

Compliance in the grain program has meant that the rotation is not as strong as it might be, "so we will come back with more manure." "I don't like to go more than two years in a row on cotton."

Fertilization strategy is based on a combination of soil tests and field history.

In general, the biggest problem with water is availability (although not this year). "We are at the bottom of the district and in past years have had delays in deliveries. Often start irrigating a little early to give myself a hedge". This problem does not occur in field 2.

GROWER B

Doesn't grow wheat because there is no money in it, although it is considered to be a clean crop which is good to grow.

Summer sugarbeets are irrigated every 2 weeks until one month before harvest; in all, over 5 feet of water (on field 3).

Likes sprinkler irrigation. "There is no question in my mind, a sprinkler program saves money." Thinks that with sprinklers you have lower insecticide costs; also cleaner and less dusty fields, and you can

get by with one less irrigation. Where land is heavy, furrow irrigation drives salts into the seed rows. If you sprinkle, you use less water and you have less of a salt problem. We know we have the deep moisture, so we sprinkle to establish the stand and then switch to furrow irrigation.

Salts (high soil salinity) give most trouble on melons and tomatoes, and less on cotton and beets. "These crops do real good on salty ground."

Fertilizer applications are based on soil analysis, although on melons sometimes apply fertilizer even if the analysis doesn't call for it.

Generally the drains are pretty quiet, "but as soon as you put water on the field they start running." When not irrigating, more running on field 4 than on field 5; however, "run more often on field 6 than on field 4."

It has been observed that the water table is higher on field 4 than on field 5.

"About the only thing that really makes a difference that we can play with is the water. This is important!"

GROWER C

Fields 7 and 8 are both in the cotton set aside program.

"When these fields were first purchased, they were level and you could grow anything." Since 1975 there have been four or five major floods and other nuisance floods. There is lot of silt deposition. On field 8 the middle is salty, and there are five soil types within a half mile. On field 7, the west side blows sand and the east side is adobe clay.

Attempted to improve soil situation with deep plowing. Ended up bringing up the salts and had to leach back down.

Some years back we grew rice in order to get rid of a morning glory problem and to leach down the salts. It worked.

Next year, will do some leveling and grow alfalfa hay as a reclamation crop. A lot of leveling is required, and the strategy is to get the flooding figured out before spending very much money on reclamation.

Sprinkler irrigation is viewed as a way of assuring germination in the sand lense areas and helping you through germination if you have salts. If you sub-up with lots of salts you end up with the salts right where you put the seeds.

General irrigation strategy as follows:

(1) If there is not a salt problem, use furrow irrigation.

(2) If there are salts, then pre-irrigate with sprinklers. Use less water but leach the salts out of the seed bed. Pre-irrigating with furrow irrigation seems to concentrate the salts while sprinkling disperses them.

(3) If the seed is planted dry, then use sprinklers regardless of the salt situation.

"The above discussion refers to cotton. With sugarbeets, never use sprinklers."

"I know one thing. If we were ever to put a drainage system in again, we would have an engineer design it who would be there when the drains went in. It would pay to do it!"

GROWER D

Went to quarter-mile runs last year. "You can save a little water, especially on field 9; you save abut 1/4 of the water."

Four years ago, because of the water shortage, started watering every other row on cotton; liked what it did, and so have adopted it to furrow irrigation on cotton.

The following strategy is used for irrigating cotton:

(1) 1st irrigation: 12 hours, all rows
(2) 2nd irrigation: 12 hours, every other row
(3) 3rd irrigation: 12 hours, every other row

On the north end of the field 10, there are high concentrations of salt; the crop shows more stress, so we give it a 4th irrigation. Also had to give an extra irrigation to the sand corner on field 11.

On field 12, only had to irrigate twice because of the high water table.

On cotton, "You have to hold the water off and force it to fruit. If you keep it too wet (i.e. don't dry it off) it doesn't fruit up."

On field 13, if it were in cotton, it would not produce very well, you would have to irrigate it one more time than field 9.

If you pull the water, the soil goes to cracking and tears the feeder roots. This cuts down production.

He is of the opinion that you could stretch the length of time between irrigations and the yields would not be adversely affected. Thinks that you could hold off an extra four or five days after each irrigation, and save one irrigation per year.

After irrigation, we have to wait 14 days to roll back the ditches, cultivate and spray.

"The new varieties of cotton do not do well if they get too wet; they will die."

General comments on irrigation:

Would rather pre-irrigate in January. "Then you know that you are going to have good, 'live' moisture when you plant. This year, pre-irrigated in early December so we could shut the ranch down."

On field 9, "When we pre-irrigate, the drainage sump pump can hardly keep up."

Doesn't grow sugarbeets, because they take too much water.

Since they got rid of the bad (salty) water, things have started to change. Cotton was going down hill.

"Before the salts started to go down, you couldn't make it here on tomatoes. You can't make it on 30-32 ton/acre tomatoes.

Since 1978, you can't make it here in small grains if you include all costs!

Grower E

Considers himself to be something of an organic gardener. Uses chicken manure which he thinks gives him about 40 units of nitrogen per acre, along with alot of trace minerals. Also notes that organic farming is not too practical in some respects.

Says that water is running out of drain on field 14. Last year almost 100 acre feet.

In general, notes that the lighter fields on the west side of the farm require more irrigation water on the crop; however, it takes more water to pre-irrigate the heavier fields on the east side.

It is his observation that the heavier fields will sub-up better during the night because the "moisture comes up better during the night."

On irrigating wheat:

Is of the opinion that the smaller the amount of water you use to grow the crop, the higher will be the protein content. Thinks that one and a half acre feet per acre is plenty of water for a wheat crop.

The reason he likes a wheat/cotton rotation is because you will get an extra 1/4 to 1/2 bale per acre on cotton following wheat, because of the value of the wheat crop residue.

Says that his yields have been coming up since he came here!

Says that if you work the ground when it is too wet, it will take you two years to get it back in shape.

The strategy for irrigating cotton is as follows: put on 4 to 6 inches after it is up, next irrigation 3 to 4 inches, and the third irrigation,

2 inches. Pre-irrigation takes about 10 inches. On the average, about 21 or 22 inches till make a crop. "With careful water management, can save about $25 per acre." "In a tight year, that's important." Water control is the key. Thinks that the problem of the future will be quality!

Can't afford to grow sugarbeets because they take too much water.

Irrigates cotton in January because "you don't want to get caught short and have to come back with irrigation around planting time. Also, after it rains, the ground will take more water, so you wait until later in the season."

Question: "Why don't you grow tomatoes?"
Answer : "I don't want to go broke!"

Grower F

With alfalfa seed, you have to keep some of the crop continuously under water stress. This induces the plants to flower which, in turn, allows the bees to be continuously gathering pollen.

Pre-irrigation is not utilized with alfalfa seed. Plant the seed, water one time, and establish the stand. You irrigate the whole field the first time in late April or early May. Then you wait until some areas of the field get stressed before irrigating again.

Can tell alot of difference in the amount of water in the drains when you irrigate.

His strategy on irrigating cotton is that on the first irrigation, he irrigates every other row at about 6" per acre. On the second and third irrigations, he irrigates every row at the same 6" per acre rate. Thinks that doing every other row facilitates fertilizer uptake.

Pre-irrigation is not used on wheat. Plant in furrows, then irrigate.

Pre-irrigation is not used on tomatoes. For the last two years, he brought tomatoes up on rain water.

Grower G

On alfalfa seed:

With alfalfa seed, it is important to create a water stress in the plant in order to cause the plants to flower. However, if there is too much stress, you will lose the whole set. It is very difficult to get the timing just right. The goal is to try to get three sets of blossoms per year.

In his experience, alfalfa seed does better on the heavier ground (which is not so good with cotton). On the lighter soils, it is more difficult to control the set.

The preferred rotation with alfalfa seed is three years of this crop, followed by cotton and then wheat. However, because of low wheat prices, he is likely to plant cotton for two years in a row.

He does not use fertilizer on alfalfa seed, figuring that it will become established using residual nutrients and then will make its own.

In general, he feels that he can do well on small grains (over 5 tons per acre). However, because of prices, he got into cotton and now is restricted on his cotton acreage. The small grains that he grows now are grown as part of the rotation, to improve soil conditions. He believes that the benefits to the subsequent crop, from the straw residue, justify leaving grain in the rotation.

More on alfalfa seed:

Historically, there were three alfalfa seed growers in the district. They got started to service a seed mill that used to be located in the area. The mill has since moved away and now you have to sell your seed in other districts.

There is a lot of variation in alfalfa seed yields due to weather. According to growers, if you have to go into October before harvesting the crop, "you are in real trouble." "If the rain hits, you could lose as much as a third of your crop." Normally, the harvest should start by the first of September and be completed by the first of October.

Tomatoes:

On field 15, the entire tomato crop was lost, six or seven years ago. Went ahead and put in a tile system. Tried tomatoes on this section last year and the crop died! Also used to grow tomatoes on field 16, but now the salts are too high. On the light soil area of this section, the salts are not a problem. However, they are a problem on the heavier soil part of the section.

Crops other than cotton do fine in fields 17 and 18.

Has use quarter-mile lengths of run for a long time.

For irrigating cotton, the first irrigation is a 24-hour set. Then use 12-hour sets for subsequent irrigations. Started doing this about four or five years ago in order to cut costs.

Has not fooled with other types of irrigation because "if you get into that, it costs a fortune." However, thinks that sprinklers might be good for establishing a stand of alfalfa seed. After the crop is up, you would have to use furrows.

On tile: Where I have tile, I don't see as much salt.

Grower H

Has a strategy of applying gypsum at the rate of 3 tons per acre, once every three years, over all of his section. Feels he gets better water penetration and dissipates the salts. "It mellows out the ground." Also has tried sulfur, but found that it did not give any results.

Next year, he will plant cotton on field 6 and use 30-inch rows, rather than the customary 40-inch rows. Feels that the cotton in this quarter section is short because of the salts. With shorter spacing, he will be growing more plants using the same amount of water, and will thus increase yields.

All of his fields are deep ripped, down to 36", every year.

Appendix 2

Quality Assurance Check

on the

Colorado State University

Soil Testing Lab

Provided by the California Regional

Water Quality Control Board

Central Valley Region

August 1987

AUG 1 9 1987

TE OF CALIFORNIA
GEORGE DEUKMEJIAN, Governor

LIFORNIA REGIONAL WATER QUALITY CONTROL BOARD—
NTRAL VALLEY REGION
3 ROUTIER ROAD
RAMENTO, CA 95827-3098

17 August 1987

Mr. Dan Nelson
Broadview Water District
P.O. Box 95
Firebaugh, CA 93640

COLORADO STATE UNIVERSITY SELENIUM ANALYSES.

Enclosed are copies of selenium analyses conducted by the Colorado State University's Soils Testing Laboratory. The samples consisted of duplicate and spiked tile drainage water from the The analytical recoveries were very good as is outlined in the enclosed copy of a leter sent to Steve Workman, the soil's laboratory director.

From what I understand of your upcoming project, you should be planning quality assurance blind duplicates and spikes to submit to which ever laboratory you choose. If you would like to discuss a quality assurance program or need help in obtaining spiked water samples, please call me at (916) 361-5689.

Jeanne Kusick

Jeanne Kusick
Land and Water Use Analyst

JEK/jk

Enclosure

E OF CALIFORNIA
IFORNIA REGIONAL WATER QUALITY CONTROL BOARD—
TRAL VALLEY REGION
S STREET
RAMENTO, CALIFORNIA 95816-7090
NE: (916) 445-0270

GEORGE DEUKMEJIAN, Governor

24 November 1986

Mr. Steve Workman
CSU Soils Testing Laboratory
Room 6, Vocational Education Building
Fort Collins, CO 80523

RESULTS OF SELENIUM WATER SAMPLE ANALYSES

I congratulate your laboratory's selenium analyses on the submitted tile drainage water samples. The recoveries for the samples were very good for the low level spike and still within 10% for the high level spike. Enclosed is a copy of the results you sent me with the spike concentrations and expected concentrations written in.

As you can see, samples JEK860924-2 and -4 were not spiked. These duplicates served as the indicated background concentrations. The recoveries on the duplicates ranged from 0.100 mg/l to 0.108 mg/l with an average background of 0.103 mg/l. Using 0.103 mg/l as a basis, expected concentrations were determined for selenite spikes of 0.250, 0.005, and 0.040 mg/l (samples -1, -3, and -5, respectively). It was encouraging to note that your procedures were able to differentiate a spike concentration as low as 0.005 mg/l. I must, however, question the number of replicates analyzed--15 replicates for 5 samples? What is your standard laboratory replicate and spiking procedure?

You should be receiving five sediment samples within the next week for participation in the total selenium round robin project. Good luck with the analyses and please feel free to call me at (916) 322--6741 if you have any questions.

JEANNE KUSICK
Land and Water Use Analyst

JEK:kwc

Enclosure

APPROVED
author
senior

Jeanne Kusick
California Regional Water
Quality Control Board
3201 S. Street
Sacramento, CA 95816-7090
Date Rec: 10/2/86

CSU Soil Testing Lab
Rm.6 Voc.Ed.Bldg.
Ft.Collins, CO 80523
(303) 491-5061

NOTE: Your samples will be automatically discarded 30 days from the date on this report unless you notify the lab to save them. Thank you.
Date:10/29/86

Research Water Analysis

Lab #	Sample ID	average Se mg/l	mg/l expected	replicates Se mg/l	Se mg/l	Se mg/l	Se mg/l	spike mg/l
W 1222	JEK86 0924 -1	0.380	.353	0.390	0.370	-----	-----	.250
1223	2	0.104	-	0.100	0.108	-----	-----	—
1224	3	0.109	.108	0.108	0.108	0.110	-----	.005
1225	4	0.102	-	0.100	0.103	0.100	0.105	—
1226	5	0.146	.143	0.143	0.143	0.145	0.153	.040

Dear Jeanne,

Please let me know what you think of these results (good or bad). We made a number of 10 µg/l (ppb) Se IV spikes and recovered the following concentrations: 10.1, 9.6, 10.7, 11.6, 11.2. Although the precision of the spike recoveries was not excellent the results indicate no serious problems in recovering Se IV from the matrix. The samples are high in soluble salts and also contain about 6 mg/l B.

Sincerely,

Steve Workman

Steve Workman

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SACRAMENTO
CVRWQCB
Nov 3 9 31 AM '86

Figures

LOCATION MAP OF BROADVIEW WATER DISTRICT AREA

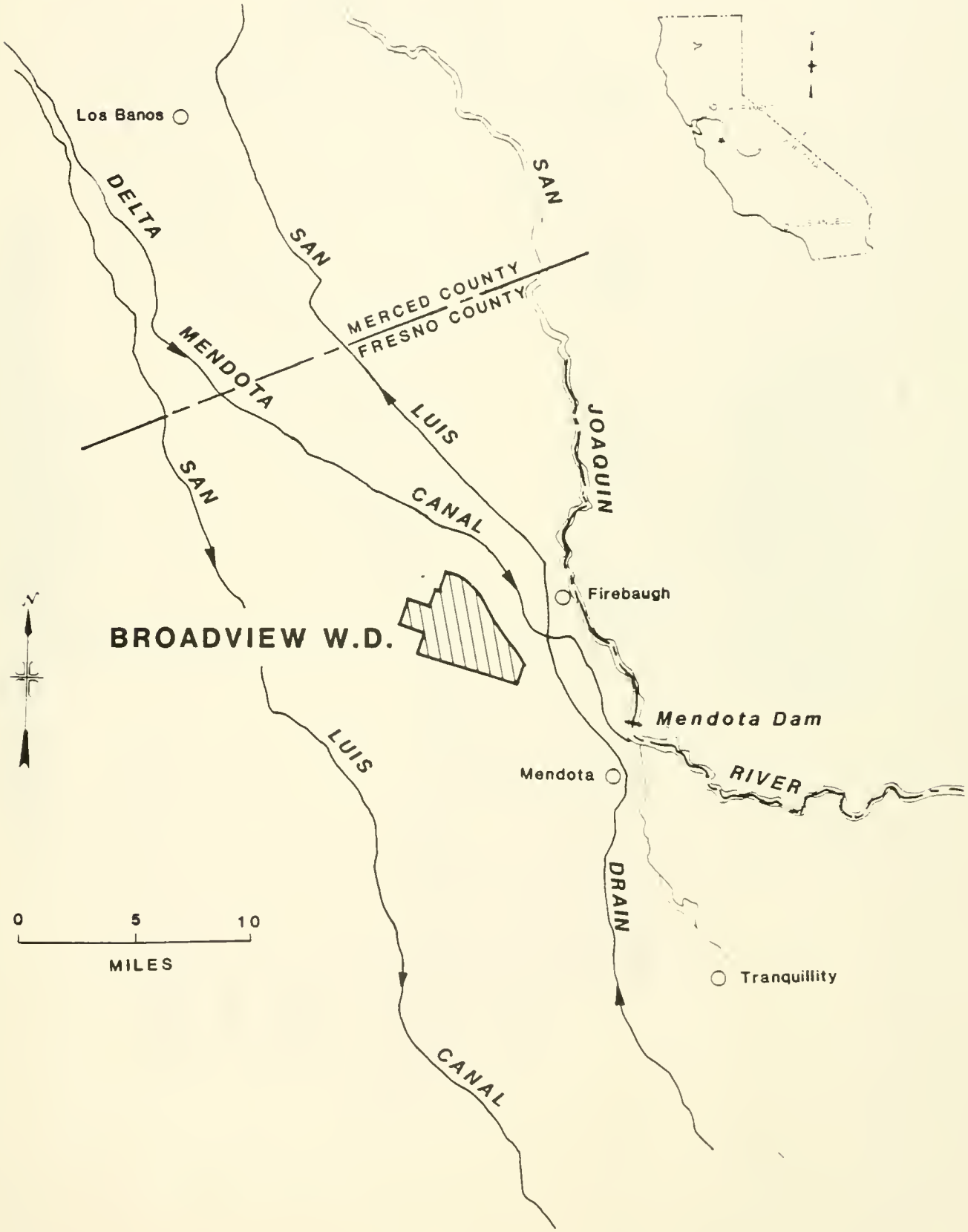


Figure 1a. Acres Planted To Cotton,
Broadview Water District and Fresno County,
1962 Through 1982

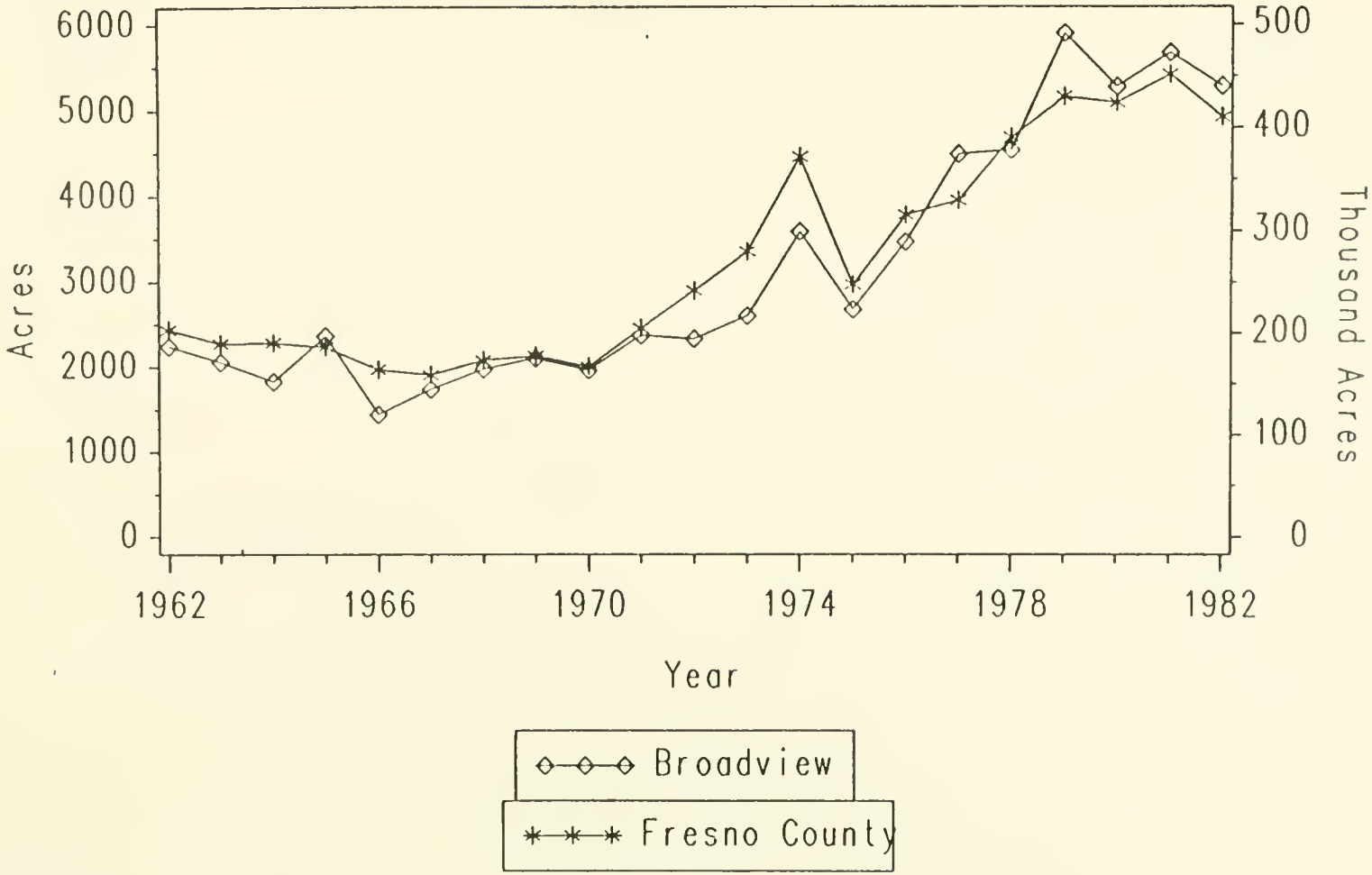


Figure 1b. Acres Planted To Tomatoes,
Broadview Water District and Fresno County,
1962 Through 1982

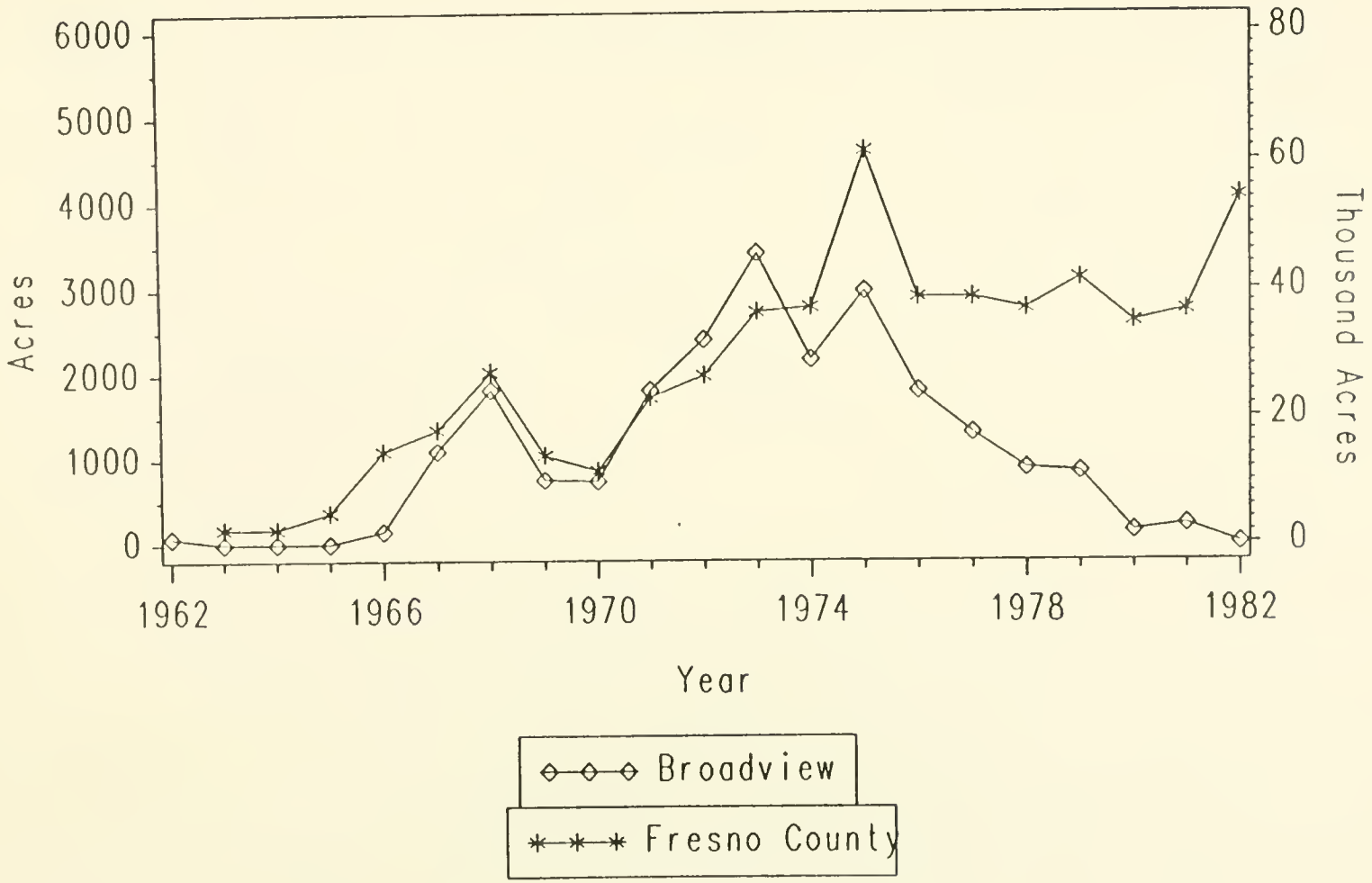


Figure 1c. Acres Planted To Alfalfa Seed,
Broadview Water District and Fresno County,
1962 Through 1982

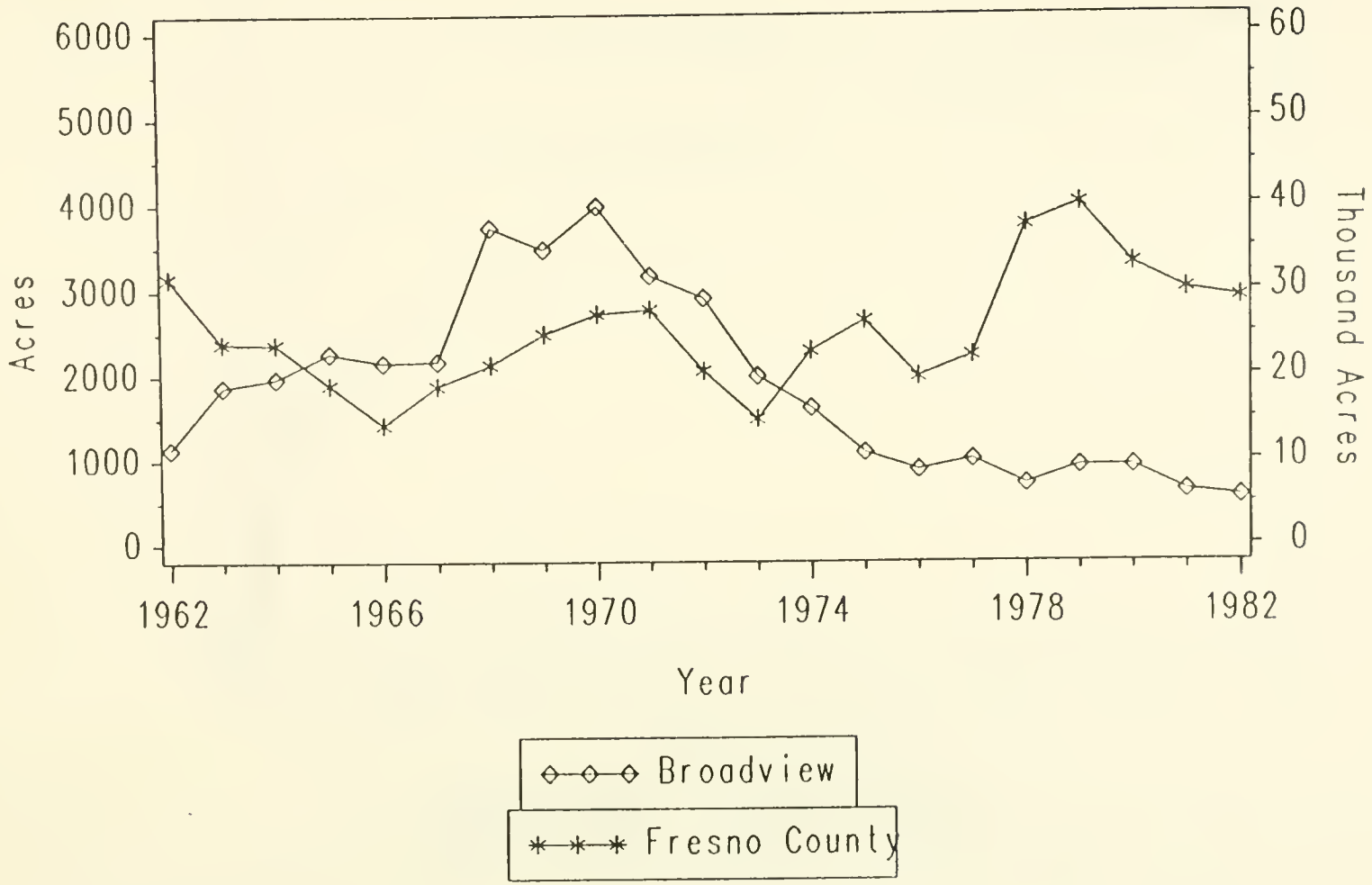


Figure 2a. Barley Production Functions
By Time Period, 1962 - 1986

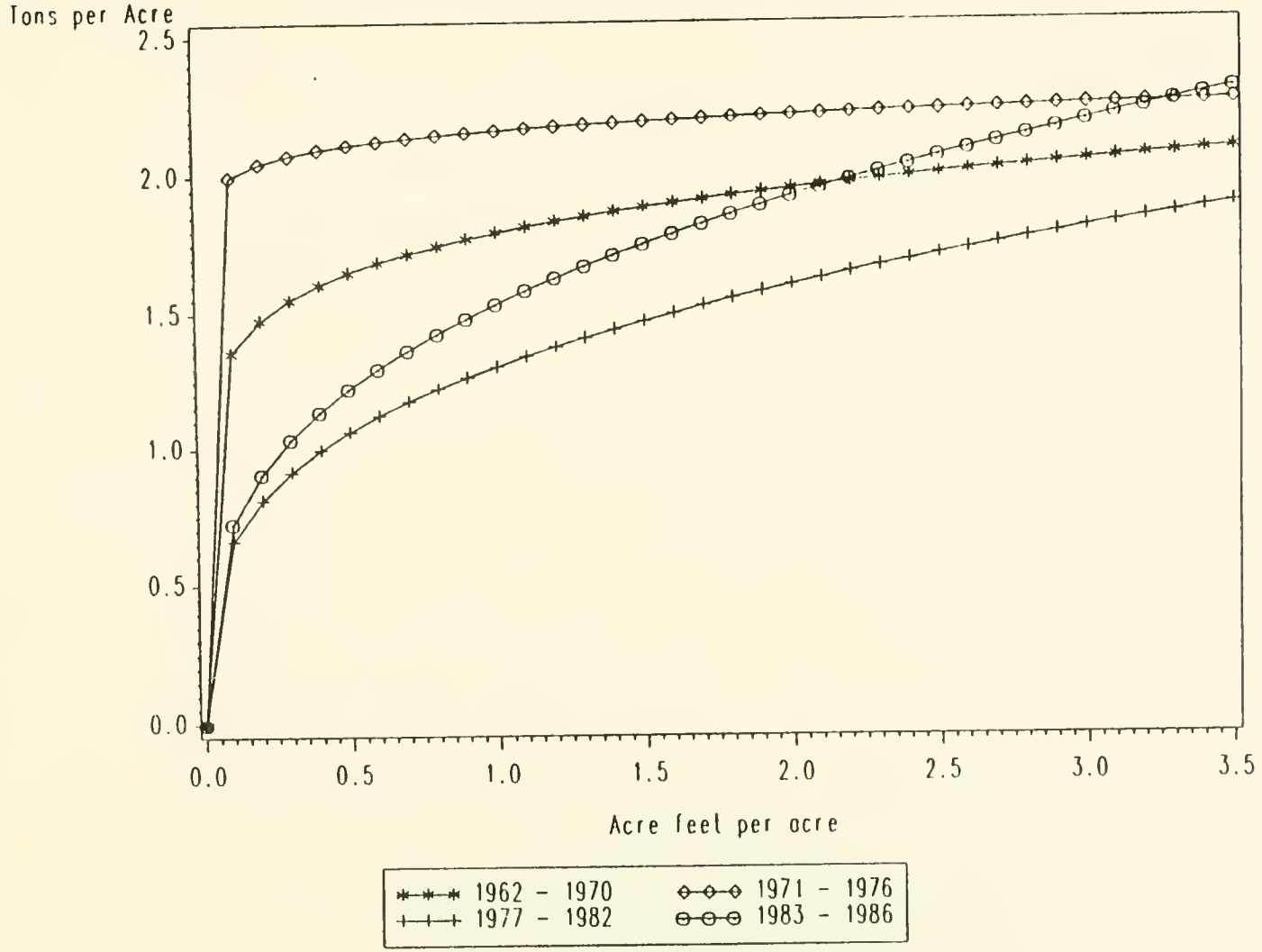


Figure 2b. Cotton Production Functions
By Time Period, 1962 – 1986

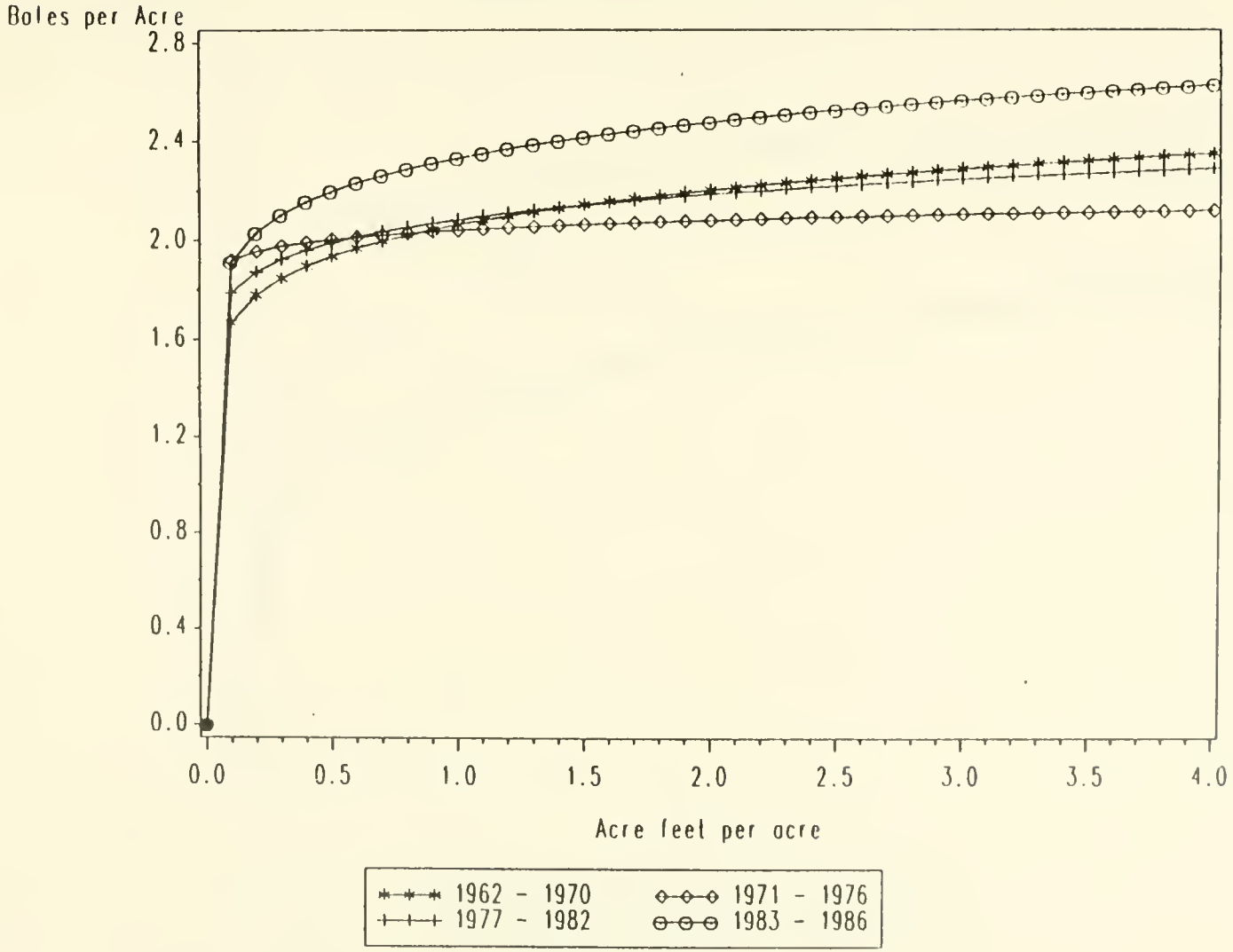


Figure 2c. Sugarbeet Production Functions
By Time Period, 1962 – 1986

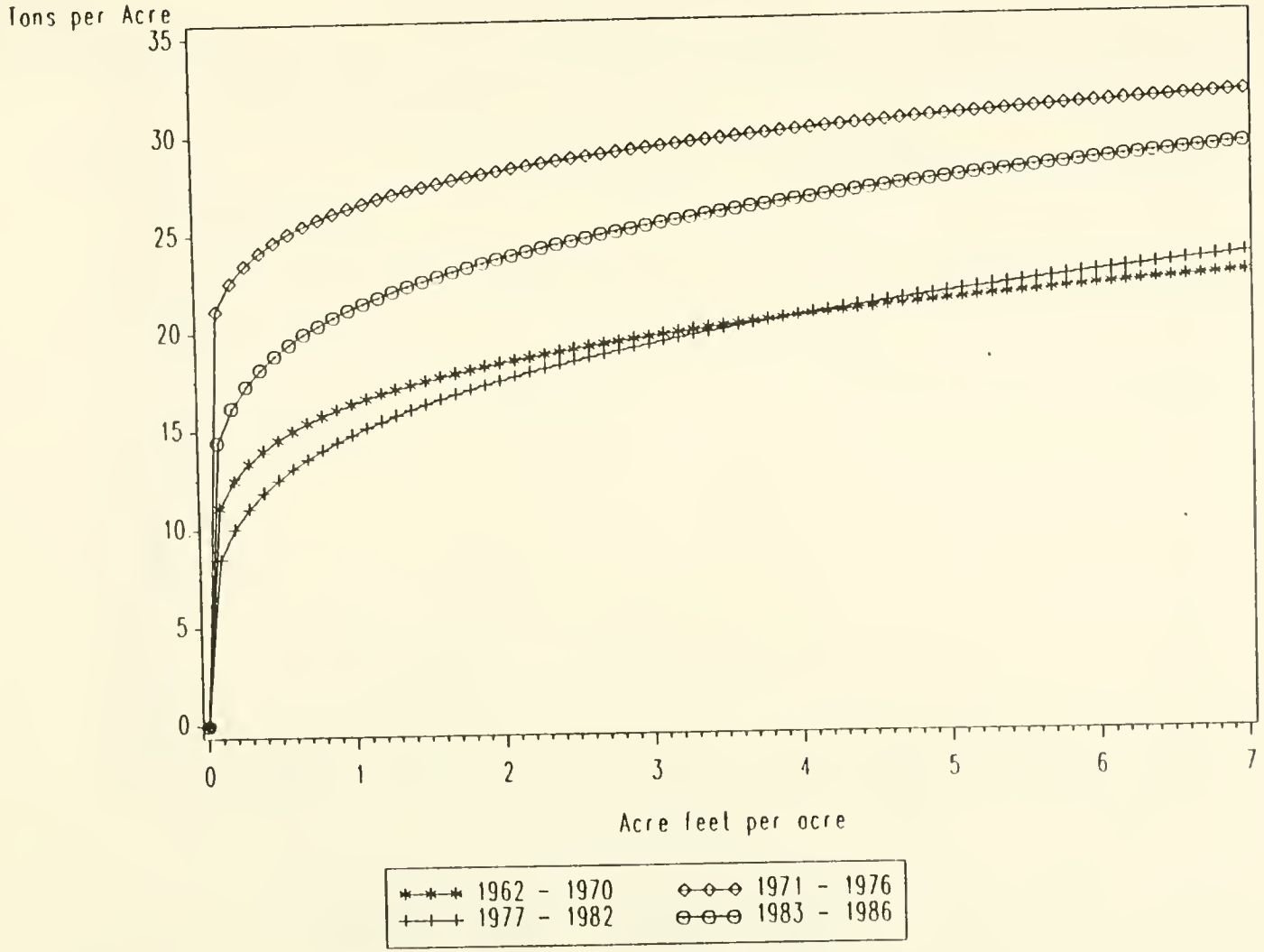


Figure 2d. Tomato Production Functions
By Time Period, 1962 – 1986

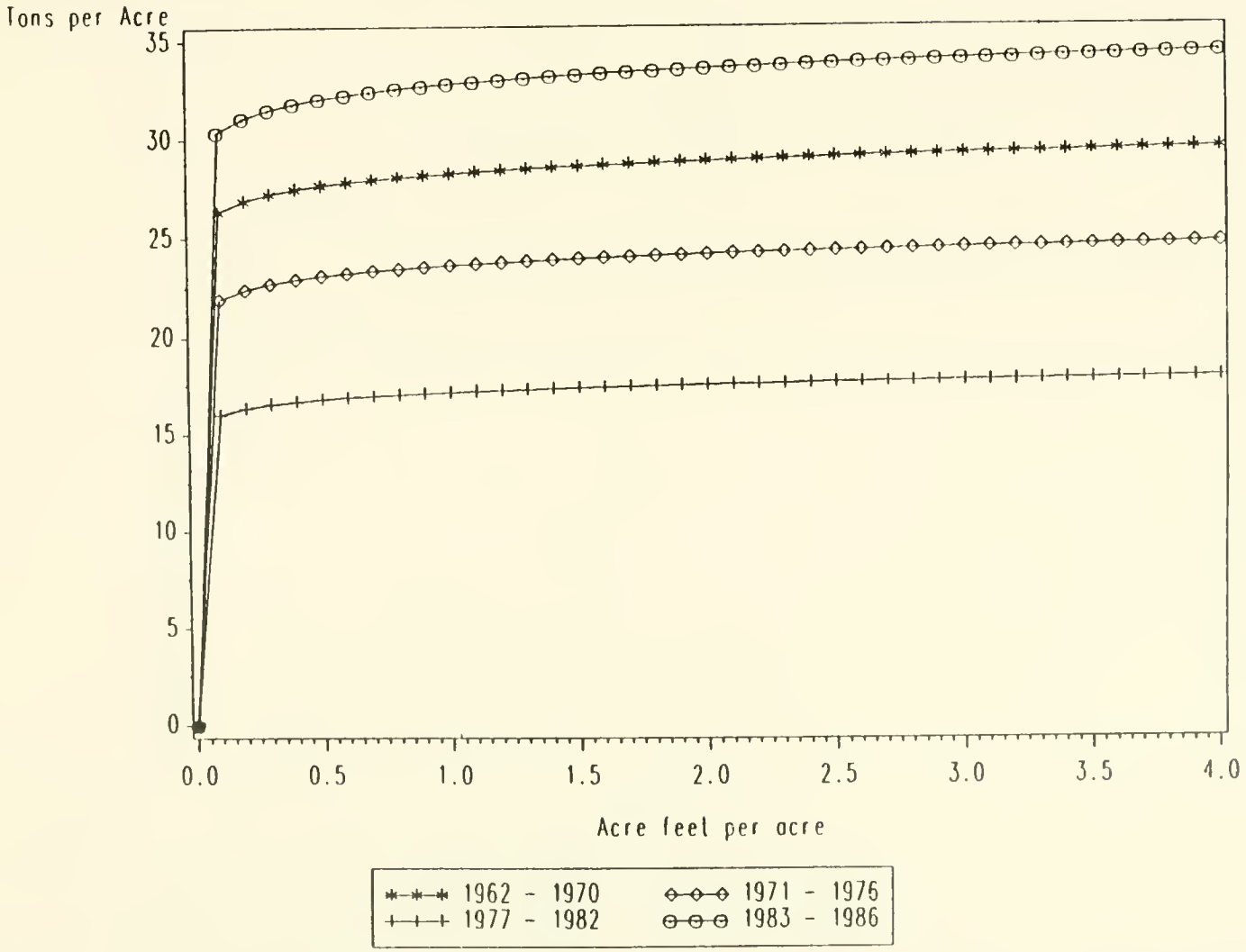


Figure 2e. Alfalfa Seed Production Functions
By Time Period, 1962 - 1986

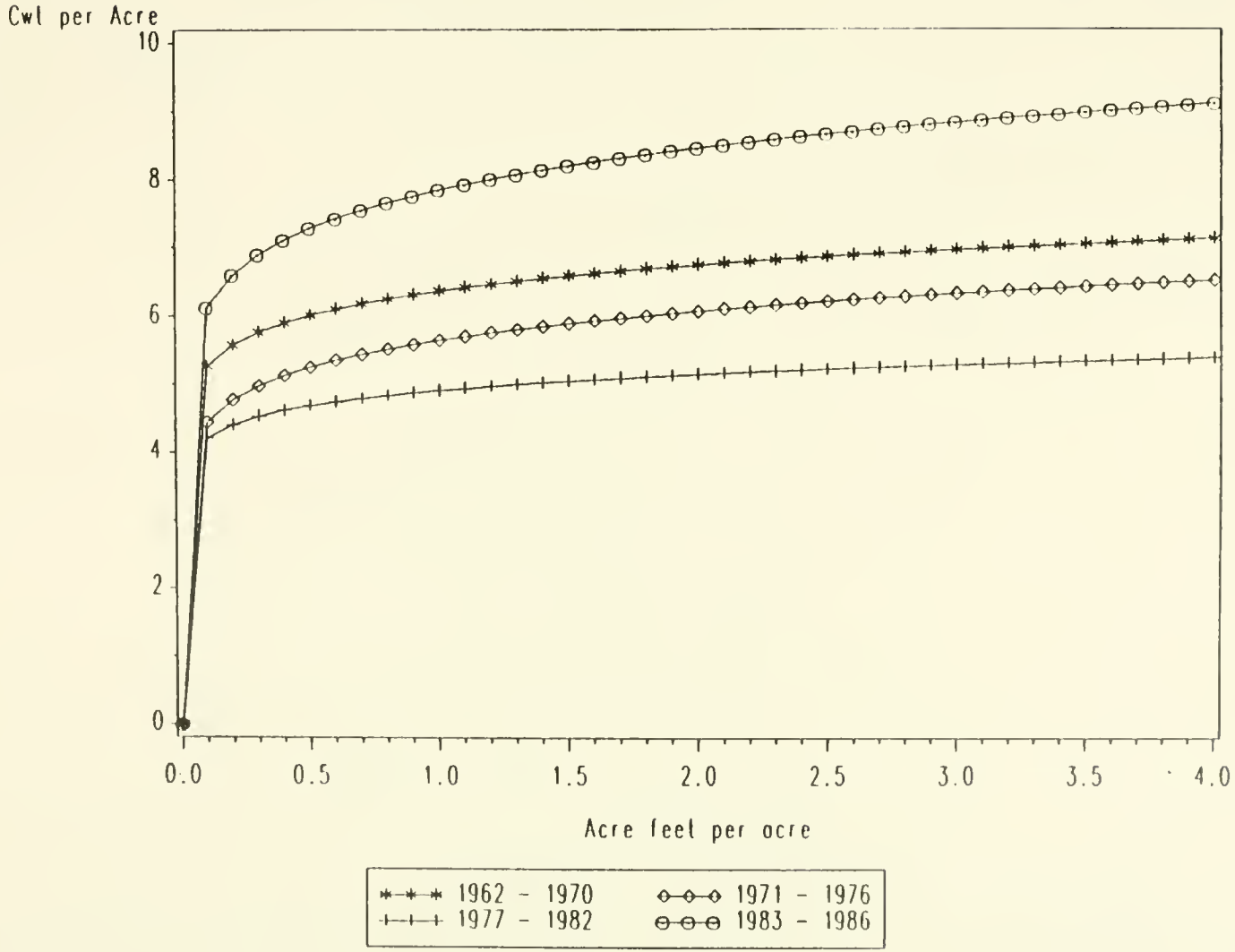
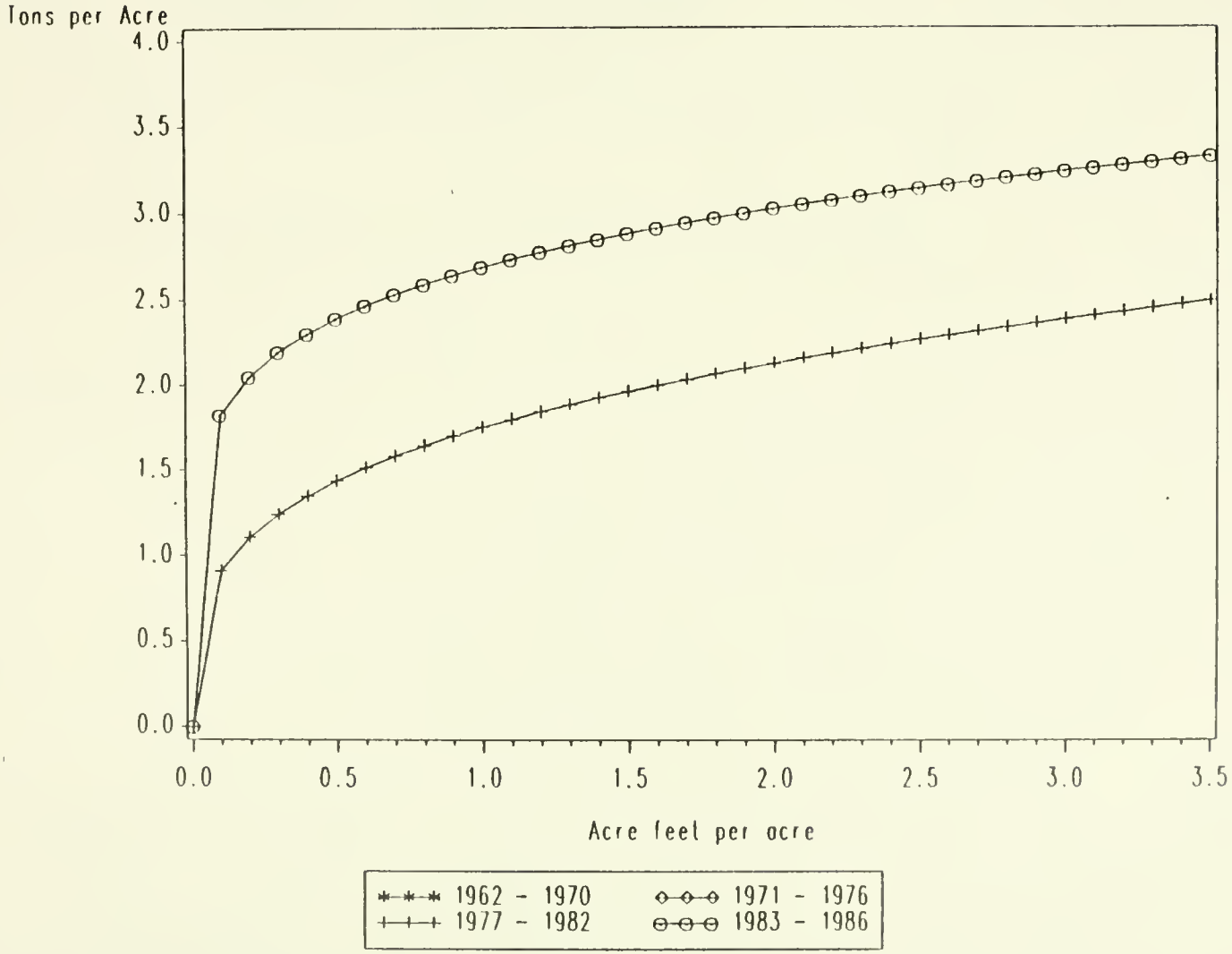


Figure 2f. Wheat Production Functions
By Time Period, 1977 - 1986



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